AN

ANALYSIS OF PHYSIOLOGY:

BEING

A CONDENSED VIEW

OF ITS

MOST IMPORTANT FACTS AND DOCTRINES.

DESIGNED ESPECIALLY

FOR THE USE OF STUDENTS.

BY

JOHN J. REESE, M. D.,

LECTURER ON MATERIA MEDICA IN THE MEDICAL INSTITUTE OF PHILADELPHIA;
FELLOW OF THE COLLEGE OF PHYSICIANS; SECRETARY OF THE
PHILADELPHIA MEDICAL SOCIETY.

PHILADELPHIA:
J. G. AUNER,—NO. 333 MARKET STREET.
1847.

WM. S. YOUNG, PRINTER.

PREFACE.

The present little work is brought before the public eye with no wish to assert any claims to originality. It is believed, however, to embrace, in a condensed form, all the most prominent facts and doctrines of the science. For several years past, during which the Author has been connected with students of medicine in the relation of preceptor, he has frequently experienced embarrassment, in his examinations on Physiology, from the want of some work which might afford a plain though complete analysis of what was taught by the best authorities upon that branch of medicine. He has been repeatedly solicited by members of his class, to prepare for them a small volume upon this subject, which they might use as a convenient hand-book. He has accordingly compiled the present "Analysis" with a view to obviate a difficulty, which, no doubt, many students have experienced.

The plan, much pursued of late, of preparing works for students, in the form of *question and answer*, does not appear to the Author to be the best adapted to impart instruction on a scientific subject; but as tending rather to render it superficial. For this cause he has adopted what has seemed to him, a more eligible mode, by which, only the most important and leading topics are presented with a sufficient degree of elucidation; but necessarily omitting many of the details, as incompatible with the size of the work.

It is proper to mention that the authors who have been most consulted, are Carpenter, Todd and Bowman, Simon, and others; and that the arrangement of the work is formed chiefly after that of Dr. Carpenter's "Manual of Physiology," republished in this country under the title of "Elements of Physiology."

It is offered to the medical student, for whom it has been especially written, with a sincere desire that he may find it a useful aid.

Philadelphia, February, 1847.

CONTENTS.

AN

ANALYSIS OF PHYSIOLOGY.

CHAPTER I.

GENERAL CONSIDERATIONS.

SECT. 1. *Organic and Inorganic Bodies.—Vegetables and Animals.*

PHYSIOLOGY is the science which treats of the actions peculiar to organized, or living beings.

All bodies in nature may be divided into two great classes,—the Inorganic, and the Organic or Organized. The former includes the mineral kingdom; the latter, the animal and vegetable. The laws of physics govern the former, whilst the latter are controlled by the laws of vital phenomena, together with the laws of physics.

Organic and inorganic bodies differ widely from each other:—1. *In Shape.* In organic bodies, the shape is constant for each species or race; with allowance for individuals. In inorganic bodies, the shape is varied and uncertain. 2. *In Origin.* Organized bodies always spring from a *parent* or *germ.* Inorganic bodies are formed by the aggregation of par-

ticles of matter, by virtue of certain forces. 3. *In Internal Structure.* Organic bodies are made up of different parts or *organs*, each of which has a different texture; the union of the whole being requisite for the perfection of the being. An inorganic body —a crystal for example—may be divided into the minutest fragments, and yet each separate atom will be a perfect representative of the original. 4. *In Size.* The size of inorganic masses is entirely indeterminate;—that of organized bodies is, for the most part, restricted within certain limits. Departures from this rule are, however, seen in the lowest order of animal and vegetable life, as in the coral, the sea-weed, &c.; but in most of these cases, the increase in size is dependent upon a continued production of *new* individuals, rather than upon a continued development of the same individual. 5. *Chemical Composition.* Of the fifty-four or fifty-five simple or ultimate elements found in the inorganic world, comparatively few enter into the composition of organic bodies—not more than *eighteen;* and of these, only *four* are considered essential, viz. Carbon, Hydrogen, Oxygen and Nitrogen. The remainder are termed *non-essential* and *accidental;* and comprise sulphur, phosphorus, chlorine, iodine, bromine, sodium, potassium, calcium, magnesium, iron, manganese, silicon, and fluorine. Some of these are extremely rare; and none of them are found but in very small quantities; being introduced for secondary purposes: thus sulphur and phosphorus are useful in forming albumen and fibrin; phospho-

rus in forming phosphate of lime, the basis of bones; and so on. Nitrogen is not essential to *vegetable* organic matter.

Inorganic bodies are chiefly *binary;* that is, are formed by the union of two different constituent atoms; and these atoms may be either *simple*, as in the union of oxygen and hydrogen to form water; or oxygen and sodium, to form soda;—or, they may be *compound*, as in the case of sulphuric acid (sulphur and oxygen) with soda, (sodium and oxygen) to form sulphate of soda. Organic bodies are rarely binary; usually they are ternary, or quaternary, or even higher.

As regards the *mode* of combination of compound bodies, there is some difference of opinion. Thus sulphate of soda may either be considered a compound of an acid oxide, (sulphur and oxygen) with a basic oxide (sodium and oxygen,) or, one of these constituents may be supposed to be decomposed, yielding one of its elements up to the other, which thereby forms a *compound radicle*, to which the other element is suited;—thus the soda gives up its oxygen to the sulphuric acid, forming with it a compound represented by SO^4, which is supposed to unite with the sodium. According to this latter view, the oxy-salts would be *binary*, instead of *ternary* compounds, just as are the chlorides, iodides, &c. This view is adopted by Graham, Daniell and others; and is of great interest when applied to the composition of organic bodies.

In compound bodies, the mere addition or sub-

traction of a single atom will often completely change their character. An example of this is given in the different compounds of nitrogen and oxygen; also in the two chlorides of mercury. But it is even more apparent in organic bodies; and this will serve to explain the numerous changes which are constantly going on in living beings. The principle of *isomerism* may also serve to explain some of these intricate changes. Bodies are said to be *isomeric* when they consist of the same elements united in the same proportions, but differing very much in their properties; starch, lignin and diastase are examples; also light-carburetted hydrogen gas and the attar of roses. Isomerism is thought to depend upon the *different arrangement* of the constituent elements of a body; but it is more probable that different compound radicles are formed, which unite with a different number of simple elements, as before mentioned.

The *tissues* of vegetables all resemble each other closely in composition. When treated so as to separate them from the different matters which they contain, the substance remaining is termed *cellulose.* It is composed of carbon, oxygen, and hydrogen,—the two latter being in the proportion to form water,—so that vegetable tissues may be regarded as *binary* compounds of carbon and water. Some of the vegetable *products* (or those proximate principles found laid up in plants) are *quaternary*,—containing carbon, oxygen, hydrogen and nitrogen; as vegetable albumen, vegetable fibrin, and vegetable

casein, which are very nearly identical with the corresponding principles of animals. The same is true also of the vegetable alkalies, as quinia, morphia, &c. There are other vegetable products which are *ternary*—as the oils, sugar, starch, &c.

Animal tissues are *quaternary*, and are chiefly composed of two proximate elements—protein and gelatin. The former of these, though of a complex nature, acts as a simple body, forming definite compounds with the different simple elements, as oxygen, sulphur, &c. The mode in which *gelatin* acts, is not so well known.

The *animal products* are generally *quaternary;* some of them, however, are *ternary*, as fat, sugar of milk, &c., but there is some doubt whether these are not really *produced* by vegetables, and passed unaltered into the animal. Berzelius regards animal products as *binary;* he supposes them to be compounds of oxygen and an organic radicle, consisting of carbon, hydrogen and nitrogen.

The *combining number*, or *equivalent* of a compound body, is high in proportion to the number of atoms which it contains; thus the equivalent of protein is 5529, oxygen being 100.

In proportion to the number of elements composing a body, is its tendency to decompose. Thus animal matter is more prone to spontaneous change than vegetable. In the latter, the elements being generally *saturated*, the structure is much more permanent. Thus a piece of wood, if kept from moisture, will last for ages. It is the *vital force*

alone, which restrains this natural tendency to decomposition in organic bodies; and this tendency is increased by *heat*. The results of these spontaneous chemical changes are chiefly gaseous; thus *carbonic acid* will be formed from the union of carbon and oxygen; *ammonia* from the hydrogen and nitrogen—*watery vapour* from the oxygen and hydrogen. If sulphur be present, it will unite with hydrogen to form *sulphuretted hydrogen;* and so on.

An important difference between vegetables and animals, is the nature of the chemical operations they effect. Thus vegetables select directly from the inorganic world the materials of their compounds—whether ternary or quaternary; and they possess the wonderful power of elaborating them from the carbonic acid, water, and ammonia supplied by the soil and atmosphere. Animals, on the contrary, possess no such power; they receive from vegetables, either directly or indirectly, all their aliment, which they simply work up into their own structure. Animals *create* nothing; vegetables alone manufacture animal matter.

Sect. 2. *Of the different Forces concerned in Organized Beings.*

By the term *force* is understood "the existence of a permanent cause producing a change in bodies." Forces can only be known by the *phenomena* which they exert in matter. Thus a muscle possesses the power of contracting under a proper stimulus; and

yet if that stimulus be not present, although the muscle possesses the *property* of contractility, still there would be no evidence of the contractile *force*, because the phenomena of contractility, as shortening, resistance, &c., would not be produced. By a process of induction, the mind infers the existence of *forces*, from the existence of the *phenomena* caused by those forces; that is, if the recurrence of the phenomena be constant, under similar circumstances.

Two opposite doctrines of forces have been maintained; one is that force is an *innate property* of matter,—the other, that it is entirely independent of matter, being the result of some *external cause*. The doctrine of the independent existence of forces is so consistent with reason, and is so well supported by arguments derived from both the organic and inorganic world, that we are led to adopt it. The force of Magnetism can hardly be said to be *inherent* in the magnetized iron; since the iron may lose its magnetism by merely being struck, though no change takes place in the iron *itself*. This is still more evident when we view the phenomena of vitality. The embryotic germ out of which the future animal is developed, is composed merely of some albumen and a little oil; yet out of this simple material are elaborated the wonderful and complex organs of the economy. Certainly it cannot be the *innate property* of albumen to form the eye, or the ear, or any other part of the body.

In living beings, we have evidence of *two* distinct

forces; these are the *Vital* or *Organic*, and the *Mechanical* or *Dynamic* forces. To these we might perhaps add a third—the *Chemical;* or preferably consider it as a modification of the first—and term it the *Chemico-vital* force.

The Vital or Organic force acts upon the amorphous organic mass, modifying it so as to produce secondary forms, and develop it into a new structure. As will hereafter be shown, all organized beings, from the lowest to the highest, have their origin in cells, or rather in germs out of which the cells are formed. These cells *grow* by appropriating the surrounding materials; thus the vegetable-cell has the power of decomposing water and carbonic acid, under the influence of the sun's light, and of combining the carbon, oxygen and hydrogen so as to form the gummy or starchy product which serves as the *pabulum* of the vegetable tissues. It is possible that thus far the act may be simply chemical, resulting from what is termed the action of *catalysis*, in which one body exerts an influence over two other bodies so as to occasion their union or separation, without itself undergoing any change. Thus it has been conjectured that the germinal molecule may exert this kind of an influence over the elements of the water and carbonic acid. The *animal* cell, as we have already seen, does not possess this power.

When this *pabulum* or organizable material is thus formed, it may undergo further elaboration by the agency of the cells, by virtue of the *chemico-*

vital force; or it may immediately be submitted to the influence of the *vital force*, by the agency of which the various tissues and organs are formed; and a *vital* character imparted to compounds, which before were not possessed of vitality: thus, the first point of *organization* may be considered to be the conversion of albumen into fibrin, or an oxy-protein.

The *dynamic* or *mechanical* forces are totally distinct from the vital. They are connected with the nervous system, and are displayed by the muscles, as their appropriate agents.

These two classes of forces require to be examined somewhat in detail. The Organic or Vital force is not only the cause of all vital action at the original development of the germ; it also presides over its whole future growth, being intimately connected with each of the successive stages in the processes of nutrition and secretion. There are certain *conditions* requisite for the display of this Organic Force, which may be termed the *essential conditions of life*. These are: 1, a certain amount of caloric. Extremes of temperature are incompatible with life; but different animals and vegetables are adapted to variations of temperature. 2. A constant supply of the organizable material to compensate for the constant waste and decay of the tissues. 3. The presence of water, which acts as the great solvent in nature, while itself is the most indifferent of all chemical substances. 4. The presence of a due supply of oxygen. As will hereafter be shown, this gas must be constantly renewed, so as to act

upon the circulating fluid. Animal heat is directly dependent upon it; and the amount of its consumption is always proportionate to the energy of the functions. Now the great object of the organic functions—respiration, digestion, circulation and secretion—is to maintain these indispensable conditions of life. They may be considered to form a circle of vital actions, which will be destroyed if any one member is absent. The organic force may be rendered *dormant*, if some of these conditions be absent. The state thus produced, may properly be denominated *dormant vitality*. It differs from *life*, because life is a state of activity; it differs from *death*, because death implies a total loss of vitality. If the necessary conditions be subsequently supplied, the organic force will again act, and all the vital functions go on with their usual energy. We have examples of this in the germination of seeds found buried with the mummies of Thebes, and which consequently must have lain dormant for 3000 years; but which, when subjected to the requisite stimuli of light, heat and moisture, vegetated as though they had been gathered only the year before. In the same way certain animals, as frogs and snails, whose vitality is always comparatively low, may be preserved for years, if frozen; and the Rotifera may be dried and kept for any length of time —yet both can be resuscitated when proper heat and moisture are applied.

All the vital actions are accompanied by certain *chemical* changes, the chief of which are the absorp-

tion of oxygen, and elimination of carbonic acid; the conversion of albumen into fibrin, casein, &c.; the productions of the various secretions and excretions, as bile and urea. Now the vital force must have a power *greater* than the natural chemical affinities, since it controls and directs them, forcing them to unite in combinations, which they would not otherwise have assumed. Like chemical attraction, the vital force acts only between the molecules or atoms of matter in actual contact; it cannot act at sensible distances. It, moreover, may be said to *resist* the external chemical changes which are continually assailing organized structures; so that when the organic force is low, these chemical agencies come into play. Finally, the organic force is exerted more in the fluids than in the solids; hence any derangement of this force is evidenced sooner in the *fluids;* in which we find disease is most apt to commence.

It remains to say a few words in reference to the *Dynamic* or *Mechanical* forces. As before mentioned, these are quite distinct from the Vital forces. The latter exist equally in vegetables and animals; the former, exclusively in animals. Although the distinction between them is decided, there is nevertheless a mutual dependence. Thus the organic actions are to a great extent *maintained* by the dynamic forces; e. g. the dynamic forces of the Circulation are requisite to keep up the proper supply of the red corpuscles of the blood, which are so essential to the different parts of the system; so also, the dynamic forces

of Respiration, (the *mechanical* acts of respiration,) are necessary to the aeration of the blood in the pulmonary capillaries; and so on. It is from this circumstance, that the two forces have so often been confounded by the physiologist and the physician.

Another proof of the distinction between them is the fact that in many parts of the system endowed with the greatest amount of vitality, as the glands and mucous membranes, the mechanical actions are not observed at all. The agent by which the dynamic powers are exerted, is the Sarcous or Muscular tissue, and the *special exitor* of this, is the nerve power, which is generated by the cerebro-spinal axis.

The mechanical or dynamic movements are various. They include:—

1. Those belonging to *Digestion*, comprising mastication, deglutition, peristaltic movements of the stomach and bowels, and the expulsive efforts of the rectum and of the ducts. The dynamic force exerted in *mastication* is often very considerable. It is particularly well seen in carnivorous animals. Mastication is accomplished by the voluntary muscles; deglutition by the involuntary muscles, through reflex action. The powers of deglutition sometimes fail in disease, constituting *dysphagia*. In the same manner, the peristaltic action of the stomach may be interfered with, causing one form of dyspepsia; and if the peristaltic condition of the bowels be affected, *constipation* may be the result, or else meteorism, or an accumulation of flatus.

Other pathological conditions of the dynamic force of Digestion are regurgitation, nervous vomiting, spasms of the stomach, and tenesmus.

Now, any one of the above pathological changes may be caused by a simple derangement of the dynamic forces; or rather of the nerve centres generating these forces. And the fact that the spinal column is divided into numerous segments—each of which is totally independent of the others, so far as *function* is concerned,—will serve to explain the curious phenomena of the entire isolation of the symptoms.

2. Those concerned in *Respiration*, including inspiration and expiration by the movements of the chest; the voice, with its modification of speech; sneezing, yawning and coughing.

The great source of the dynamic power of Respiration is the medulla oblongata. Sometimes the want of this power is manifested by loss of voice, constituting *nervous aphonia;* sometimes there is a disordered condition of the nerve centres causing dyspnœa, cough and crying; again, there may be merely a deficiency of the inspiratory or expiratory movements. From all this we may learn the importance of studying the *respiration* of patients, as a valuable diagnostic sign.

3. Those belonging to the *Circulation*. They are chiefly confined to the heart; the arteries acting principally by their elasticity. The dynamic force of the heart is very considerable, and requires a large expenditure of nerve power. It may be estimated

thus: assuming 20 pounds of blood (a low estimate,) to be constantly circulating through the system, and ascertaining by experiment that it requires four minutes for this to pass through the heart, or fifteen times in an hour; we have $15 \times 20 = 300$ lbs., the dynamic force per hour; or 7200 lbs. in 24 hours. Now it may happen that the nerve centres supplying the dynamic force of the circulation, may be disordered, causing a frequent or irregular pulse, or sudden fainting, from a want of a due quantity of blood being sent to the brain; or nervous palpitations. This is also seen in the *cold stage* of Fever.

4. *Those producing expulsion from the different cavities of the body*, as the bladder, and the uterus.

5. *Those belonging to locomotion;* including walking, running, leaping, dancing, &c., and all the various movements of the body concerned in raising weights, or overcoming resistances.

The amount of power expended in mechanical labour is very great, and has been variously reckoned. One estimate makes it equivalent to the force that would raise *two million of pounds one foot, in one day.* Another makes it equal to the force that would raise *ten pounds ten feet per second, for ten hours;* which amounts to 3,600,000 lbs. —rather too high a calculation. Coulomb's estimate is, that a man may climb a stairs at the rate of 45 steps a minute, for ten hours. The most favourable position for saving this dynamic power in mechanics, is the horizontal one: thus a man may without difficulty walk 30 miles a day; but he could not go over 2 miles, if on a perpendicular stairs.

Sometimes there is an *excess* of the dynamic power, constituting *spasm* of certain muscles. In hysterical women, there is often a sudden development of immense dynamic force. In fevers, on the contrary, there is often *loss* of this power in the external muscular system; but a concentration of it in the internal organs.

We have, too, cases of *adynamia*, or a general want of dynamic force, occurring in persons whose nutrition is perfect; but whose nerve centres do not generate sufficient power. These are frequently mistaken for *dyspepsia*, and the patient recommended to take severe exercise; which is sure to increase the difficulty. The proper remedy is *rest*, by which the nerve power is accumulated. It should also be remembered, that the greater the *rapidity* of the effort, the sooner does the exhaustion take place, and the longer does it require to accumulate.

CHAPTER II.

OF THE VITAL STIMULI.

The *essential conditions* of vitality have been pointed out in the preceding chapter. It is not sufficient that the organizable material should be perfect; the influence of certain external agents is requisite to call into action the peculiar properties of the organized structure. Thus a germinating seed contains within it a perfectly organized embryo, capable of being developed into a new being; yet it remains in a dormant state if not furnished

with the stimuli of air, heat and moisture. A familiar instance of the necessity of these agents in the *inorganic* world, is seen in the influence of light or heat upon a mixture of two gases, as chlorine or hydrogen. This mixture may be preserved unchanged, in the dark, for any length of time; but under the influence of the sun's light, a union occurs resulting in the formation of hydrochloric acid. In the same way a mixture of oxygen and hydrogen may, by the action of heat or electricity, be converted into water.

It may be observed that the dependence of organized beings upon these stimuli, is in the inverse proportion to the grade of their organization; so that beings of a simple organization are capable of enduring a deprivation of these stimuli to an extent that would be fatal to those higher in the scale.

We shall notice here the imponderables, Light, Heat and Electricity, together with Moisture, as conditions of vital action.

SECT. 1. *Of Light as a Condition of Vital Action.*

The importance of this agent in the organic world is not, generally speaking, properly estimated. We may form some idea of its value from the fact, that it is only by its influence that vegetables exert the wonderful process of converting inorganic matter into an organic compound. The simplest example of this is to be seen in the formation of the

"green matter" upon the surface of standing water, or upon damp walls or rocks, under the action of the sun's light. This matter is now known to be a *plant*, consisting of cells in different stages of development. These cells are evidently produced from pre-existing germs, and not from a direct combination of the inorganic elements; as is proved by entirely freeing the water, and also the air in contact with it, from all organic matters: when this is done, the strongest light produces no effect upon the water.

That light, and not *heat*, is the chief cause of the change, is proved by the fact that no degree of heat is sufficient, if light be absent; but a very moderate amount of heat is sufficient, if light be present.

Prof. Draper has clearly proved by experiments upon the different colours of the solar spectrum, that this force resides most in the yellow ray, or that possessed of the greatest *illuminating* power.

The changes which take place when the above conditions exist, consist in the decomposition of the carbonic acid by the cells of the plant, the setting free of oxygen, and the appropriating the carbon, which when united to the elements of water, constitutes the chief part of the vegetable fabric.

It is not quite certain how far the agency of light is necessary in the absorption of *nitrogen*, which is requisite for the formation of the azotized principles of plants.

Now, precisely the same series of changes takes place in the cells of the most complex plants; their

structure is increased, or they *grow*, by this same power of decomposing the carbonic acid through the agency of light; as may be easily shown by allowing seeds to germinate in the dark; the young plants will live for a short time, but they do not increase in *weight*, though they do in *bulk*, in consequence of absorbing water. It is only the green surfaces of the leaves, or young shoots of plants which possess this decomposing power; so that when these parts decay or fall off, this power ceases also; and a converse operation goes on, namely, the absorption of oxygen, and the giving out of carbonic acid. Thus the leaves act as the *digestive* organs of the plants, preparing products which are conveyed to all parts of their structure, by means of the descending sap, so as to become the materials for its nutrition.

There is another process quite distinct from this which is constantly going on in plants—their *respiration*. This is essentially the same as the respiration of animals; oxygen being absorbed, and carbonic acid being given out. It is carried on chiefly by the dark surfaces of the plant, and not at all by the green leaves. During day-light, it is not obvious in a healthy plant, on account of the preponderance of the other function; but it is manifest in the dark, and when the plant becomes unhealthy, or when about losing its leaves.

It is generally observed that the vegetation of places where there is a large amount of carbonic acid present, is unusually luxuriant, provided the sun's light be unclouded; and there is strong reason

for believing that in the earlier epochs of the earth's history, the atmosphere contained much more carbonic acid than it does at present; and in this way we may account for the enormous fossil vegetable remains—for instance of ferns which attained the size of perfect trees. In the same manner we may account for the formation of the vast beds of coal, which is exclusively of vegetable origin.

The influence of light is also felt upon the *exhaling* power of the leaves. Most of the watery portions of the ascending sap are thrown off by the leaves, by a process of exhalation; this process goes on rapidly under the action of light, which stimulates the *stomata* or little orifices in the cuticle of the leaves, to expand so as to allow the fluid to pass out.

During the early stages of the *germination* of plants, the presence of light is rather injurious than otherwise. This arises from the fact, that at this time a converse change from the one above alluded to, takes place; carbonic acid is given out, and oxygen absorbed. But as soon as the cotyledons are unfolded, immediately the process of *fixing* carbon is commenced. All plants do not require the same amount of light for their development; those which have thick and succulent parts, generally need most, and hence grow in the most open and exposed situations. The Cryptogamous plants require less, and are therefore met with in dark and sheltered places.

The only exception to the general law, that grow-

ing plants require the stimulus of light, is in the case of the Fungi; and this may be easily explained by the fact that their food is supplied to them by the decomposition of the substances in which they grow, and not from the atmosphere; and the rapidity of their interstitial changes involves a high amount of respiration, by which carbonic acid is eliminated and oxygen absorbed, just as in the germinating seed. The part performed by the Fungi, and many of the Moulds which attach themselves to decaying vegetable and animal matter, and feed upon their materials, is highly important in reference to the purification of the atmosphere; hence they have been, not inappropriately, named *Nature's scavengers.*

We thus observe a beautiful balance throughout Nature between vegetables and animals; the one appropriating what the other gives out.

The organic functions of Animals do not seem to be so much under the influence of light as those of vegetables; because Animals do not perform the same acts of combination from the inorganic kingdom, but make use of the products already prepared for them by plants. Hence the necessity for light is not so great. Still there is every reason to believe that the *colours* of animals are very considerably influenced by their degree of exposure to light. In this way we may account for the dark skins of the inhabitants of the tropics—the *permanency* of the hue being produced by the continued action of the stimulus, from one generation to

another. In the same way the brilliancy of colours seen in most of the birds and insects, as well as of the foliage and fruit, of tropical climates, appears owing to the brightness of the light; for it is known that if birds of a brilliant plumage be reared by artificial temperature in colder climates, they never fully acquire the same bright colours.

The *development* of animals is also much influenced by the amount of light to which they are exposed; this is particularly the case with the lowest animalcules, as those generated in water containing organic remains; their number surprisingly increasing when the light is bright. Dr. Edwards has shown that the development of Frogs from the tadpole state may be entirely arrested, if the animals be secluded from the light. There is no question that the full development of the Human race is greatly influenced by light. Thus we may witness the injurious effects resulting to the inhabitants of large manufacturing towns, where whole families are often pent up in cellars or in narrow alleys. Here, to be sure, the individuals suffer from want of ventilation, and from bad diet; but we have only to contrast the pale sickly skins of such persons, and more particularly of those who pass most of their lives in deep mines, where they become completely *etiolated* or blanched, with the ruddy complexion of the sailor or farmer, to perceive the influence of Light.

Sect. 2. *Of Heat as a Condition of Vital Action.*

Heat is one of the indispensable conditions of vitality. Its influence upon vegetation is witnessed on a large scale, by comparing the barrenness of the polar regions, with the luxurious growth of the tropics; and also in the alternations of winter and summer in temperate climates. Vegetables appear more affected by a withdrawal of heat than animals, because they have no power of generating caloric for themselves, excepting at certain periods, and in certain organs which do not impart it to the rest of the structure. The different genera and species of vegetables are endowed with different powers of enduring heat and cold. Accordingly we find peculiar races adapted to each of the varieties of climate upon the earth's surface; and when any one of these is removed from its own appropriate temperature, it either perishes, or its nutritive processes are materially interfered with.

The plants capable of enduring the *lowest* temperature are the Cryptogamic tribes, as ferns, mosses, lichens, &c.; and accordingly the proportion of these to the Phanerogamia, or flowering plants, increases, as we go from the equator towards the poles. Among flowering plants, moreover, the greatest endurance of cold is found in those which most nearly resemble the cryptogamia in development,—as the grasses, rushes, and sedges; hence these are found to constitute about *one-eleventh* of the whole of the flowering plants in the tropics,—*one-fourth* in the tem-

perate zones,—and *one-third* in the polar regions. The ratio of the Gymnospermic group of exogens—as the fir and pine,—increases in like manner.

The temperature of a place is not only regulated by its distance from the equator; but also by its elevation above the sea. The *snow-line*, or the region of perpetual snow on mountains, will of course vary according to the distance from the equator; thus under the equator, it is from 15 to 16,000 feet above the level of the sea; on the Swiss Alps, about 8000 feet. The elevation, however, is very much affected by local circumstances, as the proximity to a large expanse of sea or land; the former condition rendering the climate much colder at equal elevations.

The evaporation of moisture which is constantly taking place from the surface of plants, enables them to resist, to a great extent, the consequences of excessive heat. This ability, however, depends upon their receiving a due supply of water. If this supply be adequate to the demand, all the vital operations will be stimulated by the heat to increased energy; and unusual luxuriance of growth may result. But if the supply of water be inadequate, then the plant either withers and dies, or else its tissues become dense and contracted; as is seen in the stunted shrubs of the sandy deserts of the East. The highest temperature observed by Humboldt in the soil of tropical climates, was from 126° to 140°.

The influence of a very low temperature is well known to be fatal to most kinds of vegetation; al-

though there may frequently be a complete cessation of the vital processes—or in other words, they may be *dormant*—without the vitality being lost; a rise of temperature being only requisite, again to call them into action.

It is doubtless through *chemical* or *physical* agency that cold proves destructive to vegetation, causing congelation in the fluids, and rupture of the cells by the expansion produced in freezing. Also, there may be a separation caused between the constituent parts of the juices of the plant by the act of freezing, which may be incompatible with its functions. Hence we find that the succulent plants, which abound in fluids, are most injured by cold; and that the young shoots are more affected than the branches or trunk. Again, the viscid nature of the juices of a plant may enable it to resist the congealing influence of cold; hence the Pines, and other resinous trees, are well adapted to extremely low temperatures. It also appears that *seeds* are capable of enduring an exposure, without injury, to a temperature which would be entirely fatal to growing plants of the same species. This arises, no doubt, from the closeness of their texture, and the minute quantity of moisture they contain.

The influence of heat upon Animals is of equal importance with its effects on vegetables; though it is exerted in a very different manner, from the fact that most animals have the power of generating heat within themselves, totally independent of the external temperature. Still it is very easy to show, that

if the conditions necessary for the production of animal heat be interfered with, the animal will as certainly suffer, or even perish, as the vegetable. The *manner* in which animal heat is produced will be spoken of hereafter; it is sufficient here to remark that this power is not equally possessed by different animals;—a circumstance which has occasioned the division of them into the two classes of *warm-blooded* and *cold-blooded.*

It is from their different capacities for generating heat, that animals are adapted to varieties of climate; —those which possess this capacity to the greatest degree being always found in the coldest countries; those, on the other hand, which have the capacity least, being placed in tropical countries. Such animals cannot bear a removal to different climates, unless the temperature be artificially regulated, so as to resemble that to which they were accustomed. The human race is capable of enduring variations of climate much better than animals; though even Man requires time to become accustomed to changes of this sort.

It has been satisfactorily demonstrated by the recent experiments of Chossat, that the reduction of the temperature is the *immediate* cause of death, in starvation. This, he proved by a series of experiments upon birds; and he found that the reduction of temperature was quite regular from day to day, so long as any fat remained upon the animal; but as soon as this was exhausted, the temperature rapidly fell, and the animal soon died. But if, at this point,

it was subjected to *artificial* heat, it was immediately resuscitated; its own temperature rose, and if nourishment was given it, a complete restoration to health ensued. This affords a valuable practical hint in the treatment of diseases of exhaustion, in which the great lowering of the temperature is the *immediate* cause of death. The proper treatment in such cases, is to sustain the temperature of the body, both by the application of external heat, and the judicious administration of *alcohol*, which, from its chemical composition, is admirably adapted to furnish materials for the process of internal combustion—the usual source of animal caloric.

Among the warm-blooded classes of animals, there are some which possess the peculiar property of losing the greater part of their power of generating heat at stated times, during which their temperature is reduced very nearly to that of the surrounding medium; and their vital functions become nearly, if not entirely, dormant. The term *hybernating* is applied to such animals; and this condition appears to be as natural to them as sleep, and as periodical in its return.

An animal in the state of hybernation, closely resembles a *cold-blooded* animal, so far as regards its dependence for heat upon the surrounding medium; but it differs from the latter, in the fact of not retaining its functional activity at a reduction of its temperature, which is entirely natural to the other.

The different stages of Insect life appear to be very considerably influenced by temperature. In

the *larva* state of Insects, the temperature is but very slightly elevated above the external air. In the *pupa* or *chrysalis* state, which is one of perfect rest, the temperature is scarcely above that of the atmosphere. But in the fully developed Insect, we find a considerable elevation of temperature attained, varying, however, in different species.

Now the development of the larva from the egg, may be either hastened or retarded, simply by raising or lowering the temperature; and the development of the insect from the *pupa* state, may be influenced just in the same manner.

As respects the *degree* of heat which animals can sustain compatible with life, we find a difference among the different tribes. The higher classes and man, seem capable of great endurance. Thus instances are recorded of individuals sustaining a temperature of 350° to 500° for a short time, with proper precautions. In such cases, however, the *real* heat of the body is but very little elevated; the copious evaporation from the surface having a tendency to lower the temperature. But if this evaporation be prevented, either by saturating the air with moisture, or by not supplying a sufficient quantity of fluid within, the heat of the body then rises, and very shortly death ensues. By experiment, it has been found, that a rise in the temperature of 9° to 13° above the normal standard, is sufficient to destroy life.

As regards the greatest reduction of temperature consistent with animal life, we have already seen

that there is a great difference among the various species. As an extreme case, we may cite an instance that occurred in one of the arctic voyages, of several caterpillars having been exposed to a temperature of 40° below zero, and so completely frozen, that they resembled lumps of ice; yet when thawed, they resumed all their movements. One of them was frozen and thawed *four* times, and afterwards underwent the usual transformation into a chrysalis and moth. In the same way, fishes that have become completely frozen in ice, so as to be brittle, have revived on being thawed. Spallanzani kept frogs and snakes in an ice-house for three years; at the end of which, they revived on being warmed.

SECT. 3. *Of Electricity as a Condition of Vital Action.*

Although but little is known of the effect of Electricity upon the different functions of organized beings, there can be no doubt that an agent of such power, and one which is, more or less, constantly active, *does* exert some influence, during their different stages of development. The probable reason why this force eludes observation, is, that unlike caloric and light, it does not manifest itself so long as it is uniformly diffused, or is in a state of equilibrium; but when this equilibrium is disturbed, then the tendency to its restoration produces the familiar phenomena which manifest its existence. The well known *chemical* effect of electricity in promoting the union of two gases, as oxygen and hy-

drogen, lead to the inference that its agency in the chemical phenomena of living bodies, must also be of an important nature; but whether this agency is restricted to aiding the processes of decomposition, or whether, like light, it assists in producing new combinations, is difficult to decide.

As far as experiments can determine, there is evidence that the stimulus of a moderate amount of electricity is useful in the developement of some plants, but prejudicial in the case of others.

Even less is known of the effects of electricity upon the organic processes of Animals; although there is sufficient evidence that it acts as a powerful stimulus in certain *disordered* conditions of them. Hence, this agent has occasionally been employed as a remedy in disease,—for instance, in chronic dropsies,—by exciting the absorbent action, and for dispersing chronic tumours. But it has been found more useful, perhaps, in disorders connected with nervous derangement, in which the organic forces were not involved; so that we are not able to draw any certain inference as to its power over the *organic* functions, merely from its therapeutic applications.

Peculiar electric conditions of the atmosphere produce well-marked effects upon certain individuals, causing languor and depression of spirits.

It is well known, that certain fishes, as the Torpedo, and the Gymnotus or Electric Eel, are capable of manifesting free electricity.

Both plants and animals may be killed by shocks

of electricity; and it is probable, that one mode in which this is produced, is by the coagulation of the albumen, which is so abundant in all organized structure.

Sect. 4. *Of Moisture as a Condition of Vital Action.*

The necessity of water as a *solvent* has already been alluded to. It is equally essential to both vital and chemical action. It is impossible that nutrition should take place without the aliment being first reduced to the fluid state, so as to be absorbed into the system; and again, the different solid matters of the secretions and the excretions must become fluid before they can be eliminated; and these changes are accomplished solely by the agency of *water.*

The importance of the *fluids* may be inferred from the great proportion they bear to the solids, in organized beings. Thus the amount of water entering into the composition of man, amounts to 90 per cent. Again, the fluids invariably precede the solids in their formation, which is also an evidence of their greater importance; since, by the *law of development*, the portion of an organized being which is first produced, is regarded as the most essential, and as the *efficient cause* of those which succeed it. There are certain animals which appear to consist almost exclusively of fluids, as the jelly-fish, one of which weighing fifty pounds, may be dried down to a weight of only as many grains.

There are parallel instances among plants in the case of certain fungi.

Although no vital action can go on without the presence of a certain amount of moisture, still there are instances among the lowest tribes, both of animals and vegetables, where the entire loss of the fluids merely produces a state of *dormant* vitality, in which condition they may remain unchanged for any length of time. Among vegetables, we have examples of this in certain Mosses and Hepaticæ, which may be completely dried up, and yet be made to resume their verdure on being moistened. In like manner, the *wheel-animalcule* may be dried upon a piece of glass, and so preserved any length of time; but on being moistened, it will become as active as ever. It appears also that many of the cold-blooded animals are reduced, by a moderate deficiency of fluid, to a torpid condition, similar to that produced by cold. Many of the Mollusca, and even some Fishes, exhibit this property, becoming torpid during the heat and drought of summer, but resuming their activity on the approach of wet weather.

As the various animals and plants are differently constituted in regard to the amount of fluid contained in their tissues, so are they found dependent, in very different degrees, upon *external* moisture. There is a beautiful adaptation of plants particularly, to different situations, with this view. Thus we find the Cacti and Euphorbiæ, of the tropics, growing in the driest and most exposed

situations, often upon the bare rocks. These plants absorb a great deal of moisture, but exhale very little. On the other hand, those which grow in damp sheltered situations, exhale moisture almost as fast as they imbibe it. Animals appear to be less influenced by external moisture than vegetables; in consequence, no doubt, of the mode by which they are supplied with moisture being so very different from that on which plants are dependent. Still, the hygrometric state of the atmosphere must produce *some* modifications, though they be not very obvious. It acts chiefly, either by increasing or diminishing the exhalation of fluid from the skin and pulmonary membrane.

CHAPTER III.

OF THE DEVELOPMENT OF THE TISSUES FROM THE SIMPLE ELEMENTARY PRINCIPLES.

The only correct mode of arriving at a proper knowledge of a complex mechanism like that of Man, is to study each of its component parts, and when their individual actions are rightly understood, it will be easy to comprehend the manner in which the whole combine to produce the general result. This constitutes *analysis*, and is the method adopted in the present work.

We shall take to pieces, as it were, the complicated apparatus both of the vegetable and animal organism; and after examining the different materials of which it is constructed, proceed to build it up again, step by step.

SECT. 1. *Of the Proximate Constituents of Organized Beings.*

Although albumen appears to be the most abundant elementary product in both animals and vegetables, it may be considered as a compound of *Protein* with phosphorus and sulphur.

Protein (from a Greek word signifying, I take the precedence,) exists both in vegetables and animals. It occurs in the solid and liquid forms, and is procured from albumen, by treating it successively with water, alcohol and ether; then acting upon it with dilute muriatic acid, which removes the phosphate of lime and other salts. It is next to be dissolved in a solution of caustic potash, and thrown down by dilute acetic acid. It is in the form of grayish white flocks; and when dry, is yellowish, hard, pulverizable, and insoluble in water. Its formula is $C^{40} H^{31} O^{12} N^{5}$ (Mulder), or $C^{48} H^{36} O^{14} N^{6}$ (Liebig.) Protein unites with acids, sulphur, phosphorus and oxygen, forming definite compounds. In its natural state it is never found free from sulphur and phosphorus; thus:—

Albumen of Serum.	$Pr^{10}+S^{2}+P$.
Albumen of Eggs.	$Pr^{10}+S+P$.
Fibrin.	$Pr^{10}+S+P$.
Casein.	$Pr^{10}+S$.
Crystaline.	$Pr^{10}+S$.

Vegetable albumen, vegetable fibrin, and vegetable casein are compounds of Protein with sulphur and phosphorus, in small proportions. These

protein compounds are found in the young roots of plants in a liquid state, whence they are carried by the circulating sap to distant parts; and it is probable they are deposited in certain cells, in the solid form, through the agency of an acid, which always precipitates them from their solutions. An alkaline solution, on the other hand, would render them soluble, and would account for their removal from one part to another. Vegetable albumen, and casein or legumin, are both soluble in cold water; the former is coagulable by heat, the latter is precipitated by acids. Vegetable fibrin is not soluble in water. Besides these, there is also another named gluten. All these vegetable principles contain nitrogen, and are nearly, if not quite, identical with the similarly named principles in animals.

Protein forms two known compounds with oxygen—the *binoxide* and the *tritoxide*. The binoxide is insoluble in water; the tritoxide is soluble. Both compounds are thought to exist in small quantities in healthy blood, being produced during respiration. The tritoxide is remarkably increased during inflammation,—being found in the *buffy coat*.

Of the Protein Compounds of Animals.

Albumen. It closely corresponds with vegetable albumen, and is the material out of which all the structures is formed. Two varieties of Albumen are spoken of—the *ser-albumen*, or that contained in serum, chyle and lymph; and the *ov-albumen*,

or that contained in eggs, also in cerebrin and neurin. Albumen exists in the soluble and insoluble forms. *Soluble* albumen is found always combined with free soda, with which it acts as an acid, forming an albuminate of soda. Its solubility is believed to be owing to this combination. It may be coagulated, or converted into the *insoluble* form, by a temperature of 158°, though it requires a boiling heat if there be but little albumen in the fluid. It is also coagulated by alcohol, creasote, most acids, (particularly nitric) except acetic and tribasic phosphoric, and also by electricity. With acids it acts the part of a base; and with alkalies it plays the part of an acid. It forms insoluble compounds also with most of the metallic salts, particularly with corrosive sublimate. Albumen is found in eggs,—constituting all the white and most of the yelk, in the serum of the blood, in the humours of the eye, in the exudations of serous cavities, in the urine in disease, and in most morbid products. Soluble albumen will dissolve phosphate of lime; in this way, the material for *bones* can be introduced into the system. Albumen, as such, does not enter into the formation of any tissue; it is the point of departure where the formative process begins. All the protein compounds must be reduced to albumen by the digestive process, before they can enter into the nutrition of the body.

2. *Casein.* This is closely allied to albumen, and replaces it in milk. It exists in the soluble and insoluble forms. A small quantity of a free alkali is

necessary to retain it in the soluble form. It differs from albumen in not being coagulable by heat, and in being precipitated by acetic acid. Its coagulation is easily effected by the presence of certain animal membranes, as *rennet;* but this change is, by chemists, believed to be a species of fermentation, and to result from the influence of the membrane upon the sugar of milk, converting it into lactic acid, which precipitates the casein. Chemically, casein differs from albumen in containing no phosphorus.

Albumen and Casein are the raw materials from which the whole structure is built up, as seen in the development of the chick from the egg, and of the young mammal from the mother's milk.

3. *Fibrin.* This proximate principle is very closely allied to albumen in chemical composition. It may be regarded as albumen in which the process of *organization* is going on; and it is formed out of the fibrin, by the vital process. Its characteristic is, that it spontaneously coagulates, assuming an organized form. It exists chiefly in the blood;—also in chyle, lymph, and in the colourless exudations that are poured out from wounded and inflamed surfaces—termed *coagulable*, or *plastic lymph;* also in muscles; sometimes in the serosity of serous cavities; rarely in dropsical effusions; and more rarely still in urine. Fibrin exists in the solid and liquid form; the latter can only be maintained when in contact with living tissue. Fibrin may be best procured by whipping freshly drawn

blood with a bundle of twigs,—the fibrin adheres to the twigs in the form of white filaments. When dried, it closely resembles albumen. It is soluble in a dilute alkali. It is readily converted into albumen by the process of Digestion; and like albumen, it acts both as an acid and a base. It also unites with the earthy phosphates.

The chief point of difference between Albumen and Fibrin is the *spontaneous* coagulation of the latter. Its coagulum is organized, and shows a definite fibrous arrangement, particularly in the buffy coat of inflammation. But the most perfect specimens of fibrous structure, produced by simple coagulation of fibrin, are found in the exudations from inflamed or wounded surfaces, constituting *false membranes;* also in the fibrous coating which the ovum receives as it passes along the oviduct, which afterwards becomes the shell. The completeness of the production of such tissues depends, partly upon the degree of elaboration of the fibrin, and partly upon the nature of the surface on which the coagulation takes place.

In the Blood, the fibrin is believed to be in a state of solution, and it retains its fluid state as long as it is in motion, in the living body. But its fluidity is not *caused* by motion, since no degree of movement, out of the body, can prevent its coagulation; and when enclosed between ligatures in a living vessel, it does not immediately coagulate; *vitality* evidently influences it. It is moreover probable, that fibrin is never allowed to remain fluid any

length of time, being withdrawn from the blood, by the nutritive process, as soon as it is elaborated.

4. *Pepsin.* This is an organic protein product, contained in the epithelium cells of the stomach, and thrown out during the process of digestion. It is coagulated by heat and alcohol and is thereby rendered insoluble. It is distinguished by the part it plays in Digestion; and it will be more fully spoken of under that head. Pepsin is, by some, not considered a protein-compound. Vogel's formula for it, is $C^{43}\ H^{32}\ N^{8}\ O^{10}$.

5. *Pyin.* A peculiar matter found in Pus, resembling casein and chondrin, in some respects. It is soluble in water, but is precipitated by alcohol. Mulder regards it as a *protoxide of protein.*

II. *Gelatin, and its modifications.* By some physiologists, Gelatin is not considered as one of the proximate elements of animals, but is regarded as a *product* rather than an *educt.* It is procured, by long boiling, from the white fibrous tissues, as the skin and areolar tissue, tendons, ligaments, mucous and serous membranes, and some forms of cartilage. It is not known to exist in a fluid state, nor has it been found in the blood. The peculiar tissue constituting true cellular cartilage is named *Chondrin*, and is, by many, regarded as a mere modification of gelatin; and the term *Glutin* is given by them, to what they consider the other variety. They differ from each other in several respects;—gelatin (glutin) consists of $C^{13}\ H^{10}\ O^{5}\ N^{2}$; chondrin of $C^{32}\ O^{14}\ H^{26}\ N^{4} + S$.

Both are dissolved by long boiling, and are converted into *glue;* but chondrin requires a longer boiling. Gelatin is precipitated by tannic acid, but not by acetic acid ; chondrin, on the other hand, is precipitated by acetic acid, alum, and acetate of lead, but *not* by tannin.

It is not known how gelatin is produced in the animal body. It is evidently elaborated in some way, out of albumen, since it is found in young animals fed solely on albuminous matters, and also in herbivorous animals. Mulder supposes it to be, by the decomposition of protein by the agency of weak alkalies in the blood, and of oxygen in respiration.

III. *Hæmatin.*—Another proximate constituent of animals;—it exists in the red corpuscles of the blood, forming the interior or colouring matter; the exterior or cell-wall, is composed of *Globulin.* It will be spoken of under the head of Blood.

IV. *Salivin,* or *Ptyalin,*—is found in the salivary and pancreatic fluids, combined with extractive.

The above are the principal azotized proximate principles found in animals. There are some others which it will suffice merely to mention here,—as the colouring matter of bile, bilin, choleic acid, urea, uric acid, hippuric acid, uric or xanthic oxide, and some others.

The *non-azotized* principles comprise a second class of proximate animal elements. The chief of these are: the *saccharine,*—as sugar of milk, and sugar of diabetes; *fatty substances capable of*

forming soaps,—as the fat acids, and glycerin; *fatty substances not saponifiable,*—as cholesterin and serolin; *organic acids,*—as lactic, oxalic and acetic.

The combination of the above proximate elements constitutes the *Tissues;* the union of the tissues forms the *Organs,* which are "Instruments designed for executing some specific function," as the lungs, the stomach, the liver, &c. An *Apparatus* is an assemblage of different organs, all of which contribute to one ultimate end, but each of which has its specific function;—as the digestive, respiratory and circulatory apparatus. An *Organism* is a collection of all the organs to form an individual. The unity of the whole constitutes a single existence.—In the animal economy there may be said to be a myriad of existences, each one acting independently of the other, and yet all harmonizing in perfect concord. This unity of action is produced by several causes: as by the Vital force which is exerted upon each molecule;—by one common fluid, the *blood;*—by Nervous communication connecting together the different parts of the system. This connexion may be either *synergic,*—as when there is a combination of the different organs of an apparatus for one common end; or *sympathetic*—where there is a combination of organs, but no function resulting, and no salutary purpose answered.

Before proceeding to the different tissues of the animal structure, it may be proper to give a tabular

sketch of them. It is impossible to arrange them in a perfect classification; but the following table prepared by Todd and Bowman will serve the purpose.

Tabular View of the Tissues of the Human Body.

1. Simple membrane, homogeneous, or nearly so, employed alone or in the formation of compound membranes.	Examples.—Posterior layer of Cornea.—Capsule of Lens.—Sarcolemma of muscle, &c.
2. Filamentous tissues, the elements of which are real or apparent filaments.	White and Yellow fibrous tissues. —Areolar tissue.
3. Compound membranes, composed of simple membrane, and a layer of cells of various forms (epithelium or epidermis,) or of areolar tissue and epithelium.	Mucous membrane.—Skin.—True or Secreting glands.—Serous and Synovial membranes.
4. Tissues which retain their primitive cellular structure as their permanent character.	Adipose tissue.—Cartilage—Gray nervous matter.
5. Sclerous or hard tissue.	Bone.—Teeth.
6. Compound tissues	
a. Composed of tubes of homogeneous membrane containing a peculiar substance.	Muscle.—Nerve.
b. Composed of white fibrous tissues, and cartilage.	Fibro-cartilage.

The opinion is held by some Physiologists that *every* tissue necessarily originates in cells; others of equal authority, maintain that this rule is not universal. We shall speak first of those which are believed *probably* to originate without cells, and then treat of those of cellular origin.

SECT. 2. *Of the Simple Fibrous Tissues, and their Modifications; not necessarily originating in Cells.*

A considerable part of the body is composed of simple fibrous tissues, in which the fibres are merely interwoven together, just as they are in the coagulum of inflammatory blood, or in the false membranes which are the results of inflammation. These fibres are solid, and have only *physical* powers, which serves to distinguish them from both muscular and nervous fibres, which are hollow, and possessed of *vital* properties. The simple fibrous tissues serve to bind together the different parts of the body. The arrangement of the fibres depends upon the functions of the tissue into which they enter; thus in *tendons*, which connect muscles, and bones together, they are parallel; in *ligaments* which connect bones together, and which resist strain, the fibres often cross each other in every direction. The structure of the fibrous membranes, which surround certain organs, as the heart, is similar. In the fibro-cartilages, there is a mixture of bundles of fibres, with cartilaginous cells.

There are two forms of fibrous tissue, the White and the Yellow, or the unyielding and elastic. They may be distinguished by the action of acetic acid, which causes the white to swell up and become transparent, and brings into view certain oval corpuscles supposed to be nuclei of formative cells; whilst upon the yellow it produces no effect. The white usually occurs in bands, marked by longitu-

dinal streaks; the yellow, in long single branched filaments from the 1-5000th, to 1-10,000th, of an inch in diameter, often anastomosing with each other. It is found especially in parts requiring elasticity, as in the middle coat of the arteries, the vocal cords, the ligamentum nuchæ, particularly of quadrupeds, and the ligamenta subflava; also in other parts which are usually considered cartilaginous, as the external ear. They differ also in *chemical composition;* the white fibrous tissue, as ligaments, tendons, &c., being composed of Gelatin, or rather converted into it by long boiling; the yellow being scarcely affected by boiling, or by weak acids, and supposed by Scherer to consist of Protein and two atoms of water.

The simple fibrous tissue is but sparingly supplied with blood, and it is but slightly susceptible of change.

The *Areolar* or *Cellular tissue*, like the simple fibrous, is composed of minute fibres interwoven together, so as to leave innumerable *areolæ* or little spaces, which communicate with each other. Part of its fibres are of the yellow or elastic sort, but the majority are of the white variety. The interstices are filled, during life, with a fluid resembling dilute serum of the blood. It is very elastic and extensible in all directions. It has not, properly speaking, *vital* properties, for its sensibility is dependent upon the nerves which pass through it, and its contractility upon the muscular tissue of the vessels which traverse it.

The areolar tissue abounds in nearly all parts of the body; thus it binds together the different muscular fibres, forms septa between muscles, unites the elements of nerves, glands, &c., and binds together the fat-cells. It is not, at present, believed to penetrate the hard tissues, as the bones, cartilage, and teeth. Its design is to allow a certain degree of mobility of parts, and it serves as a bed for nerves and vessels.

The quantity of fluid in the areolar tissue varies; it is dependent, not upon any *secreting* power of the tissue, but merely upon the transudation of the watery portion of the fluid circulating in the vessels. If there is a want of *tone* in the walls of these vessels, there is an increased tendency to transudation, constituting one form of dropsy; the elasticity of the tissue is destroyed by the effused fluid, and the part *pits* on pressure. The free communication between all parts of the areolar tissue, is seen, in the influence of gravity upon dropsical effusions; and still more, by the whole body becoming distended from an emphysema of the lungs.

The *Serous* and *Synovial membranes* are composed, essentially, of areolar tissue. Their free surface is covered by an epithelial layer, which lies upon a basement membrane. Below this, is a condensed layer of areolar tissue, which gradually passes into a looser texture, constituting the *sub-serous* layer. The fibres composing these tissues belong to the yellow or elastic variety; hence they are yielding and elastic. Their fluid resembles the

serum of the blood; and it is probably merely the effect of transudation from the vessels, and not a proper secretion. In the synovial capsules and bursæ, there is a greater proportion of albumen.

The *Mucous membranes* and *Skin* are also made up chiefly of areolar tissue. These two textures may be considered as continuations of each other, only modified in different parts according to the functions to be performed. They are every where extremely vascular, but the vascularity of the skin is chiefly destined for the nervous system, and is necessary for general sensation, while that of the mucous membranes is subservient to secretion and absorption. The skin and mucous membranes are merged into each other at the various orifices and outlets of the body; thus we have the *gastro-intestinal*, the *bronchio-pulmonary*, the *genito-urinary*, and the *mammary* mucous membrane, and some other smaller divisions. Hence, the great distinction between serous and mucous membranes, is in regard to their *arrangement* as well as their *function*. For while the former are shut sacs, whose contents are not designed to undergo much change, the latter constitute walls of tubes and cavities, which have free communication with the outer surface, and in which, constant change is taking place. All the Organic functions are performed by the system of mucous membranes.

The composition of Mucous membranes and Skin resembles that of the serous membranes; both consist of an epithelium or epidermis, a basement membrane,

and the proper areolar tissue, with its vessels, nerves, &c. The epithelium and epidermis consist of cells,—those of the epidermis being arranged in several layers, and designed merely to afford protection to the subjacent texture, while those of the epithelium are connected with the processes of secretion. The basement membrane resembles that of serous membranes;—it is particularly evident in the tubuli uriniferi of the kidney. The areolar tissue of the skin is very distinct; it contains both sorts of fibres, and hence it yields *gelatin*, on boiling. The skin also seems to contain some non-striated muscular fibre. The skin is far more abundantly supplied with nerves than the mucous membranes; hence the sensibility of the former is very acute,—that of the latter, very low.

The Areolar tissue is capable of speedy regeneration, as seen in cases of loss of substance. As to its precise *mode* of production, microscopists are not determined,—some thinking it due to the transformation of cells, others to a simple coagulation of fibrin, under peculiar circumstances.

Sect. 3. *Of the Basement Membrane.*

The term Basement Membrane is applied to the very thin membranous structure which is placed immediately beneath the epidermic or epithelial cells, on all the free surfaces of the body. It was called *basement* by Mr. Bowman, as being the foundation upon which the epithelium cells rested; by Mr. Goodsir, it was named *primary membrane*, as fur-

nishing the germs of those cells. It appears to be made up, like the areolar tissue, directly from the coagulation of fibrin; its appearance being homogeneous, and presenting no trace of structure. Todd and Bowman ascribe its formation to the flattening and fusion of the cell-walls into one another. It is found in the skin, and in the mucous membranes, being prolonged into the minutest ducts and follicles of glands; also in the serous and synovial membranes, in the blood vessels and lymphatics. The Basement membrane is the medium through which the cells derive their nourishment; but its chief office seems to be to furnish new generations of cells, in the place of those which are cast off; and it is probable that the granules which are often observed diffused through it, are the germs of cells to be developed from its surface. It is not a permanent structure, since it is continually undergoing disintegration on its free surface, and must be as constantly renewed upon the surface next to the blood vessels.

CHAPTER IV.

OF THE TISSUES ACKNOWLEDGED TO BE FORMED FROM CELLS.

Sect. 1. *Of the General Doctrine of Cells.*

By the term *cell* or *vesicle*, in physiological language, is meant a minute closed sac, whose walls are composed of a delicate membrane, and whose contents may be of a varied character. All the vege-

tative or organic functions of living beings are performed by the agency of cells. Each cell is, in fact, a complete organism; having its own separate and independent existence, performing its allotted office, and then either dying out and giving place to its successors, or else remaining as a permanent part of the structure. Some of the lowest forms, both of vegetables and animals afford examples of simple cells;—it is well seen in the *Protococcus Nivalis* or *Red Snow*, a cryptogamic plant found in the polar regions, capable of extremely rapid production by means of germs. The Fungi and Moulds are only a more complex arrangement of similar cells.

Cells appear to originate in two modes; either in the midst of an organizable fluid, or *blastema*, when in contact with a living tissue; or in the interior of previously-formed cells. Both these modes may be observed by the microscope, in the elaborated sap of vegetables, and in the unimpregnated ovum of animals. The first step perceived, in the process of organization, is the appearance of numerous minute granules, which render the fluid partially opaque. According to Schleiden and Schwann,—the original observers,—these granules aggregate together to form larger granules, termed *nucleoli;* several of these combining to form the *nucleus*. Others suppose that the nucleus is formed directly from the original granules. Be that as it may, a spot can generally be distinguished in the centre of the nucleus, which is the nucleolus. From the nucleus, is developed the Cell; but in what *mode*,—has not been

certainly determined. According to one theory, the nucleus pushes out its walls on one side, as a watch-glass projects from the dial; the membrane gradually projects more and more until it completely surrounds the nucleus. From this circumstance, the name *cytoblast* or *cell-germ*, is applied to the nucleus. According to the other view, there occurs a sort of precipitation around the nucleus, of the fine granular matter; and this forms the cell-wall. The contents of the cell are taken in by the principle of *endosmose.*

The second mode by which cells originate, is from the interior of a previously-formed cell. As already stated, the nucleus of each cell consists of an aggregation of granules, each one of which is believed to be the germ of a new cell; and its development may either take place within the parent-vesicle, so that this becomes filled with the successive generations of cells, as in the case of the ovum, and also in the permanent tissues; or the parent-cell may rupture, scattering its contents, which then become fully developed.

The nucleus and cell-wall differ in composition; the former is acted upon by acetic acid, &c., the latter is not. The cell-wall is composed of a protein-element, probably the tritoxide of protein. Several nucleoli may often be seen in one nucleus, just as several nuclei are observed in a single cell.

As regards the question, whether a cell can ever be formed without a nucleus,—there are some instances which *appear* to support the positive view,

as in the case of the red corpuscles of the blood of mammalia, the white corpuscles of the blood, the chyle and lymph-corpuscles, and the epithelium-cells,—none of which have been certainly *proved* to be nucleated-cells; but which are supposed by Mandl to be formed from the original granules, without the intervention of a nucleus.

The subsequent *form* assumed by cells is extremely variable, depending, to a great extent, upon the degree and direction of the pressure to which they may be submitted; sometimes they are spheroidal, sometimes cuboidal or prismatic, and sometimes cylindrical or very much prolonged. Their subsequent *transformations* are also various, sometimes by great elongation they are converted into fibres; again, they may become perfect tubes, by a number of cells joining together, the partitions at each extremity being removed,—as seen in the muscle and nerve-structure of Animals, and in the sap-tubes of Vegetables. Another transformation of cells is where their structure remains persistent, but they become filled up with new matter,—as the fat-cell, the cells of cartilage, bone, teeth, &c. In all these instances, the *nucleus* appears to take no part in the formation of the tissue; it may often be seen unaltered in the structure; but again, there is evidence, according to Henle, that the nucleus may *itself* be prolonged into a fibre without the intervention of a cell. Thus in areolar tissue, we find one set of fibres soluble in acetic acid, and another set which are insoluble; the former of these may be derived from cells, the latter from nuclei.

From what has been stated, it is evident that the processes of Nutrition and Secretion consist mainly in the growth of individual Cells; the materials for this growth being supplied from the blood.

The Simple Isolated Cells will be first spoken of, together with the tissues which they compose.

Sect. 2. *Of the Simple Isolated Cells.*

By this term is intended such cells as are separate and disconnected, to distinguish them from those which are united together in the composition of the tissue. Their chief points of difference from the permanent cells, is their transitional state, and their origin—as is supposed,—not from a *nucleus*, but from a reproductive granule. This distinction was pointed out in the preceding Section. There is one important difference between the animal and vegetable cells:—the latter possess the power of assimilating from *inorganic* bodies, converting them into organic compounds; the former have no such power; all that they do is to appropriate what has been already *produced* by vegetables. The animal-cell has the power of *selecting* from the materials of which the nutritive fluid is composed, and perhaps of *transforming* one compound into another, (though this is uncertain,) but they can *produce* no organic compound. The composition of the cell-wall appears to be always the same—from Protein; the great distinction is, as to the *contents* of the cells.

The best examples of simple isolated cells, are found in the Corpuscles of the blood, the chyle and the lymph; the particulars of each of which will be discussed in another place. Each of these corpuscles is entirely independent—quite as much so as the cells of a simple vesicular plant; they will only grow and multiply in an animal albuminous fluid.

The *Epidermic* and *Epithelium Cells* come next in independence. The epidermis and epithelium are continuous with each other, and are precisely similar in structure, though not in function; the epidermis being designed merely to protect the skin, while the epithelium, by means of its cells, performs the important function of *secretion.*

The Epidermis or Cuticle was formerly thought to be an inorganic exudation from the skin, and to be homogeneous in texture. It is now known to consist of several layers of cells, the outer ones of which are continually being thrown off, giving place to those beneath; the successive crops being supplied by the basement membrane. This desquamation is sometimes particularly rapid, as after Scarlatina.

In the gradual progress of the cells from the inner to the outer surface of the epithelium, they become changed in form. The innermost layer consists of nuclei in various degrees of development into cells, soft and granular. This was formerly considered a distinct tissue, and named Rete Mucosum, being supposed to be the seat of the colour of the skin. Passing from this layer outwards, we find the cells

assuming a spherical form, then becoming polygonal, and gradually flattened, until at the surface, they are merely dry scales. The flattening results from the drying of the contents from exposure to the air. The number of these layers varies in different parts of the skin—being greatest in those places which are subjected to pressure, as the palms of the hands and soles of the feet. The Epidermis is continuous with the epithelial lining of the ducts of the Sudoriparous and Sebaceous glands.

The *Nails* are only an altered form of epidermis, being the product of cells, which gradually dry into scales; and these remain adherent. A new growth is constantly occurring at the grove of the skin in which the nail is fixed, and also, probably, from the whole subjacent surface.

The composition of the epidermis is similar to that of hair, horns, nails and wool. Its sole object seems to be to protect the skin. When abraded, it is rapidly regenerated.

The *Pigment Cells* are found intermingled with the epidermic cells. They secrete the colouring matter. They are not very evident in the white, but are well marked in the dark races. Their growth and development are like those of the epidermic cells. They are particularly evident on the inner surface of the choroid coat of the eye, constituting the *pigmentum nigrum*. Their form is polygonal. Their dark colour is thought to be owing to a great number of granules existing in the cells. They contain a large amount of carbon. The growth of

these cells is dependent somewhat upon the influence of *light*. An occasional development of them occurs during pregnancy, particularly in the areola of the nipple. On the other hand, a deficiency of them sometimes exists, either partial or entire; this occurs both in the white and black, and such persons are called Albinoes.

The *Epithelium* is continuous with the epidermis at the various outlets of the body; also over all mucous membranes, with their prolongations into follicles and glands; also over serous and synovial membranes. Like it, it is composed of layers of cells; but these cells being in contact with fluids, do not dry up as the epidermic cells. They are the true agents in all the secretions.

There are two kinds of Epithelium,—the *pavement* or *tesselated*, and *cylindrical*. The former is composed of flattened polygonal cells lying in apposition with each other, forming a kind of pavement. It is found in serous and synovial membranes, and in the lining of the heart and blood-vessels; also in some of the mucous membranes, as that of the mouth and respiratory organs. The epithelium of Serous membranes appears endowed with less activity than that of Mucous membranes.

The *cylinder epithelium* is composed of cylindrical cells, arranged side by side, with one extremity resting upon the basement membrane, and the other extremity free. The perfect cylindrical form of these cells is only seen when the surface upon which they rest is flat. If it be convex, they have

a conical shape, the apex being towards the basement membrane. If concave, the apex is towards the free surface. The cylinder epithelium is well seen in the villi of the intestines.

Both forms often pass into one another, and are frequently fringed with delicate hair-like processes termed *Cilia*, which vary much in size,—from the 1–500th to the 1–13,000th of an inch. They are usually flattened and tapering, and present an almost constant wavy motion. In the lower aquatic animals, their function seems to be to renew the water in contact with their surface, for the purpose of aeration, and also to serve as organs of prehension and locomotion. The *cause* of ciliary motion is not known. It does not depend upon either nervous or muscular energy, since it is unaffected by either electricity or narcotics. It seems independent of the will, and even of the life of the animal, since it has been seen in isolated epithelium cells many days after death; but the length of time is much less in warm-blooded animals. The sole conditions for the ciliary movement appear to be the integrity of the attached epithelium cell, and the presence of a fluid.

In Man, cilia have been observed in the nasal cavities, frontal sinuses, maxillary antra, lachrymal sacs and ducts, posterior surface of the velum pendulum, the Eustachian tube, the larynx, trachea and bronchi, the uterus and the Fallopian tubes. In all these positions the cilia are attached to the cylinder-epithelium; and their function evidently is to propel the secretions to the external orifices, as

their direction is *outwards.* They have been found also in the brain; but here their function is unknown.

The epithelium-cells of mucous membranes secrete *Mucus.* This is a transparent tenacious substance, insoluble in water, but dissolved in weak alkaline solutions, from which it is precipitated by acids In some parts, a sufficient supply of mucus is afforded by the cells upon the surface of the membrane; but in other situations, as in the alimentary canal, the demand is much greater; hence the use of the numerous follicles and crypts to extend the surface. The remains of these cells, after they have burst and poured out their contents, are thrown, as effete matter, into the intestines. The cells which lie upon the surface of mucous membranes, have their origin in the germs of the basement membrane. Those which are found in follicles seem to occupy rather the cavity than the walls, and to be reproduced from a *germinal spot* in the blind extremity of the follicle. The same is true of the ultimate follicles of glands.

Hence, we see that secretion is only a process of *cell-growth,* the various cells taking up, from the blood, the materials necessary for their nutrition; bursting or wasting away, and discharging their contents into channels which communicate with the exterior of the body. In many cases all that the cells effect, is the mere separation from the blood, of substances pre-existing there, as the fat, &c.;

in other instances, they exhibit a power of transforming, decomposing, or combining the pre-existing elements. It is not certain that they ever really *create* a new product, although the secretion of milk, and of the spermatic fluid, are believed by some to be instances of a true creative power in the cells. This is the highest power which cells possess; it is termed the *metabolic force*, by Schwann.

The *Reproductive Cells*, by which the germs of a new being are furnished, are found in the tubuli of the testicle. These cells contain the *Spermatozoa*, or small ovoid bodies, with a long tapering extremity, appearing from their spontaneous motion like animalcules; but their movements are of the same nature as those of the vesicles of plants. They are thought to be nothing more than cell-germs, furnished with a peculiar power of motion. More will be said of them under the head of Reproduction.

The *Absorbent Cells* of the alimentary canal resemble other simple isolated cells, except that they constitute a part of the substance of the fabric, instead of lying upon its free surfaces, and being continually cast off by them. A cluster of these cells exists at the end of each intestinal villus, while absorption is going on, during digestion. Their function is the converse of that of the secreting cells; for they draw their materials, not from the blood, as do the latter, but from the nutritious matter which has passed down into the intestines from the stomach. When they burst or liquefy, they discharge their contents into the *lacteal* which is found in each

villus, and not into a duct by which they may be expelled. Each villus, however, is covered by a protective epithelium, which, as in other cases, is composed of cells. During the intervals of the digestive process, the villi are flaccid, and exhibit only a collection of germs; but as soon as food is received, they become turgid and erect, and the absorbent cells which lie beneath the epithelium, are rapidly developed by the absorption of the nutritious matter; and at the same time, the epithelium cells are detached from the surface of the villus, so that the absorbent cells may come into direct contact with the nutriment. The *debris* of the epithelium cells is thrown into the alimentary canal, as effete matter; while the *debris* of the absorbent cells passes into the lacteals. Again, while the germs of the epithelium cells are furnished by the basement membrane, the absorbent cells furnish their own germs.

Cells similar in function and structure to the absorbent cells, are found in the embryo of the chick and mammal. In the former, the contents of the yelk-bag are taken up by the vascular layer of the germinal membrane, through the medium of cells; and in the latter, the fœtus receives both its nutrition and aeration through the medium of the cells of the placental villus.

Thus it appears that all the Organic functions are performed by means of a *cell-growth.* The causes which increase or retard this growth are not always evident. For instance, while the

absorbent cells appear to depend for their development simply upon a due supply of nutritious material and of blood, the secreting cells seem to require something more for their development; since an excess of materials destined to be separated from the blood may accumulate in that fluid *because* the secreting cells are not sufficiently developed; whilst, on the other hand, the presence of certain matters in the blood appears to increase their development: thus mercury increases nearly every secretion, or in other words, accelerates the growth and development of the secreting cells. Again, this development seems to be under the influence of the mental emotions, as in the case of milk, gastric-juice, tears and saliva. But this may arise chiefly through the influence of the capillaries and the Sympathetic nerve.

Sect. 3. *Of Cells connected together in Solid Tissues.*

The more permanent and solid tissues of the body have their origin in cells which are more or less closely connected together by an envelope, or by an intercellular substance. These permanent cells do not, like the isolated cells just spoken of, originate in floating germs, but they are developed within a parent-cell, which may remain persistent. These secondary cells, even while within the parent-cell, may be developing a third generation within themselves. The rapidity of the reproductive process depends greatly upon the character of the structure

as to whether or not it is permanent. The most rapid development is met with in cancerous growths; but in more permanent structures, the development within the parent cell is more limited; thus, in the embryo of mammalia, it is limited to two cells, which are named the *twin cells*.

In the development of the *nucleus*, it is the outer circle of its granules that is first changed into young cells; the next circle then commences, pushing the preceding one outwards, and by the continuance of this process, the parent-cell may be completely filled with a new generation. (Barry.)

Sometimes the walls of the parent-cells become thickened by additional nutrition, and remain as permanent vesicles, enclosing numerous secondary cells,—as in the *Adipose* tissue, and in some tumours; sometimes the walls thin away, in which case the permanent cells are held together by an intercellular substance, usually gelatin; and the quantity of this substance in proportion to the cells, may vary very much. In some forms of Cartilage, we find minute cells widely scattered over a very large amount of intercellular substance; in others, again, the cells are more developed, and the amount of intercellular substance is less.

The Hard tissues are formed by a deposite of earthy matters in the cells; thus shells,—by the deposition of carbonate of lime; bones and teeth,—from carbonate and phosphate of lime. In such, there seems to be a *coalescence* of the cells, by the removal of their partition, or rather of the intercellular substance.

The formation of *tubes* occurs by the union of a number of cells in a row, and the subsequent breaking down of the intervening partitions; thus the sap vessels of plants, the capillary vessels of animals, and the ultimate muscular and nervous fibres, are formed, as already alluded to.

The cells may undergo various alterations in form either from subsequent pressure, or independently of it; thus we find the *polygonal*, the *stellated*, and the *fusiform*,—the latter form being a frequent product of morbid growth.

The *Adipose tissue*, or *Fat*, is composed of cells which secrete the fatty matter from the blood. The Fat-cells may be either scattered throughout the areolar tissue, being held in their place by fibres, or else collected in small clusters and covered by a common envelope, on the outside of which the blood-vessels ramify. This last is the proper adipose tissue. Each of these masses of fat-cells resembles a gland, except that there is no excretory duct,—the secretion being stored away instead of being thrown off.

The Fat-cells are spheroidal in shape—often of an irregular form from pressure. Their intervals are filled up by delicate capillaries. Their walls are moistened by a watery fluid, by which means the transudation of their contents, (which are liquid at the temperature of the living body,) is prevented.

The consistence of Fat varies in different animals, being dependent on the relative proportions of the constituent principles, stearine, oleine, and marga-

rine. Of these, stearine is the most solid, resembling spermaceti; it melts at 143°. Margarine is also solid, and is usually found along with stearine. It is the principal solid ingredient in the Human fat, and in olive-oil. It melts at 118°. It resembles stearine, but is more soluble in alcohol and ether. Oleine is the fluid constituent of fats. It remains fluid, when pure, at zero, but is soluble in cold ether. It is found chiefly in liquid fixed oils. All these three principles are neutral compounds of *stearic, margaric* and *oleic acids*, respectively, with a base named *Glycerin*. Glycerin may be separated from its acid, by acting upon any fatty substance with an alkali, which unites with the acids, forming a soap. Stearine, oleine, and margarine are nearly identical in their ultimate composition; they contain no nitrogen, and very little oxygen; but a large proportion of carbon and hydrogen, (C^{142} H^{141} O^{17}).

The secretion of fat seems to be accomplished by a very simple process. No actual *elaboration* is, in most instances, requisite, since fatty matters exist so abundantly in both vegetable and animal food; these are simply taken up unchanged. In some cases, however, animals have the power of elaborating fat out of the sugar or starch of their food. The Adipose tissue only comprises that portion of the oily material which remains after the other important purposes of fatty matters have been answered. It is the *overplus* laid by for future use; and it subserves several purposes,—thus it fills

up interstices, and forms pads for the support of moveable parts; it acts as a non-conductor of heat: hence its use to animals inhabiting cold climates. It is a reservoir of combustible matter to maintain the Respiration when other materials are deficient: by this means the respiration is kept up in hybernating animals during the winter. A considerable lowering of temperature occurs in animals starved to death, so soon as all the fat disappears.

Cartilage, in its simplest form, consists of permanent cells scattered through a substance which strongly resembles gelatin, and which, by some, is ranked as a species of gelatin; it is named *Chondrin*. It requires longer boiling to dissolve it, and is not precipitated by tannic acid; but it is, by acetate of lead, acetic acid, alum and sulphate of iron, which do not affect gelatin.

All the fœtal cartilages are composed of chondrin; but as soon as ossification commences it gives place to gelatin; there being no chondrin in the bones. The *permanent* cartilages, however, still contain only chondrin, but if bony deposits take place in cartilages, then it is replaced by gelatin. Chondrin corresponds more with protein in its composition, than does gelatin. Chondrin is found exclusively in the true cellular cartilages; the fibro-cartilages, ligaments and tendons yield gelatin.

Cartilage likewise contains some mineral matters, as the sulphate and carbonate of soda; carbonate and phosphate of lime. The latter increases in quantity as age advances, causing a disposition to *ossification*.

The cartilage-cells are multiplied by a sort of doubling or division, each separate portion forming for itself an envelope out of the intercellular substances. They are known by the name of *cartilage corpuscles.* Some cartilages retain throughout their primitive cellular form,—as the articular cartilages, the cartilages of the nose, the eyelids, the trachea, the bronchi, and the larynx (except the epiglottis;) also the cartilages of the ribs, and the ensiform cartilage. *Fibro-cartilages* are formed, when the hyaline, or intercellular substance, assumes a fibrous character; and this may be elastic, or non-elastic. The fibrous character is seen in those cartilages which unite the bones by *synchondrosis*, as in the vertebræ and pelvis. The yellow fibrous cartilage is seen in the epiglottis, and concha of the ear.

Like the tissues already described, the cells of cartilage are nourished without coming into direct contact with the blood. No vessels penetrate the cellular cartilages in a state of health. They are however, surrounded by vessels, which form *ampullæ* or varicose dilatations at their edges, or on their surfaces: from these the cells are nourished by imbibition; those which are nearest receiving the nutriment and transmitting it to the more remote. In a state of inflammation, vessels are seen in the substance; but it is believed that these vessels exist in a new tissue developed by the inflammation, and not in the *true* cartilage.

When undergoing ossification vessels are seen in them; they do not, however, ramify extensively, but leave large islets unsupplied.

The fibro-cartilages are more vascular,—but in them, the vessels do not penetrate the *cellular* portion.

Cartilage has comparatively little vitality, and hence, resists decomposition for a long time. It is doubtful whether a loss of substance is ever repaired by true cartilaginous tissue.

The *Cornea* closely resembles cartilage, particularly the cellular form; but the cells are less numerous. There are two sets of vessels surrounding the margin of the cornea, the superficial belong rather to the conjunctival membrane; they project over the cornea about one-eighth of an inch, and then return as veins. The deep-seated layer does not pass into the true cornea; the vessels terminating in veins just where the sclerotic coat is joined by the cornea. In inflammation, both sets of vessels extend through the cornea. The superficial vessels sometimes form an elevated band around the margin.

The *Crystaline Lens* also resembles cartilage in its structure. It is composed of fibres which are united into laminæ by a process of interlocking of their margins. The fibres are made up by a series of delicate cells, which coalesce at an early period. In the healthy state, it is not permeated by vessels, these being confined to its capsule. The lens is chiefly composed of albumen, or of a matter resembling globulin.

The *Vitreous Humour* is made up of a cellular structure, which contains a transparent fluid consist-

ing of water holding albumen and saline matter in solution. The cells have no very direct communication with each other. It is not permeated by blood-vessels, these being spent upon its envelope, and contributing, along with the plexus of the ciliary processes, to afford it nourishment.

Sect. 4. *Of Cells altered by a deposition of earthy matter in their Substance.*

This mode of alteration of cells is seen in Bones and Teeth.

I. *Of Bones.* The general characters of the osseous tissue vary according to the shape of the bones. The long bones have their shaft composed of a compact structure, which is pierced by a central medullary canal. Their extremities are made up of cancellated structure, the cancelli freely communicating with each other, and with the cavity of the shaft; the whole being covered with a thin lamina of solid bone. In the thin flat bones, as the Scapula, the two hard surfaces are connected together by cancellated structure. In the thicker flat bones, as those of the Cranium, their cancellated structure is more evident, constituting the *diploë*. Again, in some very thin lamellæ, as the Ethmoid and Sphenoid bones, we find but a single layer of osseous matter.

Although a thin lamella of bone appears to be homogeneous, it is found, when viewed by the microscope, to consist of minute granules cohering through the medium of gelatin. In the midst of

these, numerous dark spots of a peculiar radiating appearance are observed, which are named *osseous* or *Purkingean corpuscles.* These were formerly thought to consist of calcareous matter, but are now known to be only *lacunæ* or open spaces; and the rays proceeding from them are very minute tubes, called *canaliculi.* These passages are too small to admit the blood globules; but they may allow the fluid parts of the blood to pass, and thus conduce to the nutrition of the bony structure. The nutrition is effected, just as in cartilage, by imbibition through cells, which are placed between the lamellæ and the blood-vessels, which are minutely distributed over the delicate membrane lining the cancelli. This membrane is continuous with that which lines the cavity of the shaft.

The mode by which the *solid* parts of bones are nourished,—such as the shafts of long bones, and the external plates of the flat and thick bones, is by means of the *Haversian canals.* Their diameter varies from 1–2500th to 1–200th of an inch. They form a net-work in the interior of the hard structure, and transmit blood-vessels. In the long bones, these canals run in the direction of the shaft, and they communicate freely with each other, with the cancelli, and with the exterior surface. They are lined with a membrane which is continuous with that of the external surface, and also with that of the central cavity, and the cancelli; and between the osseous substance and the vascular membrane, there is a layer of cells, as in the case of the cancelli. Thus

it appears that the whole bony texture is enclosed in a membrane, upon which radiate blood-vessels, that supply the nutritive materials, through the intervention of cells.

The *medulla*, or marrow, does not seem concerned in the nutrition of bones. It is altogether absent in the bones of Birds; the cavity, in them being filled with air, which is admitted from the lungs, thus being subservient to aeration.

Bones are composed of *animal* and *calcareous* matter. The calcareous matter may be entirely removed by digestion in weak nitric or muriatic acid. The substance left is the animal matter, which is cartilaginous in its appearance, and consists of gelatin. The calcareous matter may be isolated by the action of a heat sufficiently strong to destroy the animal matter. This leaves all the calcareous matter in a very friable state. The calcareous matter is composed of the phosphate and carbonate of lime, —chiefly the former. In callus, exostosis, &c., the proportion of the carbonate is much greater than in the healthy bone; but in *caries*, it is less. The composition of the phosphate of lime in bones, is three atoms of acid, united to eight atoms of base, (Graham.) Some chemists have thought there was a little fluoride of calcium in bones, also phosphate of magnesia, oxides of manganese and iron, and chloride of sodium, in very small quantities.

The relative proportion of animal and calcareous matter in bones, varies in different animals, also in the same animal according to the age; and even in

different bones of the same skeleton. Young bones contain most animal matter; those of old persons, most earthy matter, which renders them more brittle. This brittleness also, at times occurs as a congenital defect, rendering the subject of it very liable to fractures. The more solid bones contain a larger amount of calcareous matter than the more spongy ones; thus the Temporal bone contains $63\frac{1}{2}$ per cent, whilst the Scapula has but 54 per cent.

The shells of Invertebrata grow in a very different manner from the bones of vertebrata. In the former, the growth takes place only by additional deposites upon the *surface;* in the latter, by an *interstitial* deposite. The Corals, for instance, are not built up, as was formerly supposed, by little animals, as the bees construct their cells; but the calcareous matter, (carbonate of lime,) is deposited in the cells of the living tissue, as a *true secretion* of these cells, from the surrounding water. The amount of animal matter in this structure is extremely small, hence it is not liable to undergo change. A stem or branch of coral *grows* only by superficial deposite; so that it is only the surface of such structure that is, properly speaking, alive; the great mass being perfectly inert. In this way, the growth of coral may proceed to an indefinite extent.

The shells of the Mollusca are formed, and grow in a similar manner. The univalve shells, as that of the snail, are always conoidal, the large end being open, through which the animal can protrude itself. In these, the new deposite occurs upon the

open extremity, by which means the cavity is enlarged. In the bivalve shells, as the oyster, the deposite is made in a similar manner; each successive lamina being interior to the preceding, or next to the living surface of the animal; but it also projects beyond it so as to enlarge the capacity of the shell. These laminæ are easily seen in the oyster. The proportion of calcareous and animal matter varies in different shells. In some, the organic matter can scarcely be detected, but in others it is so abundant as to assume the form of a thick membrane when the calcareous matter has been removed by an acid. This membrane is evidently made up by an aggregation of cells, either hexagonal, or of a prismatic elongated shape, in which the carbonate of lime is deposited.

The same mode of growth is found in the Crustacea and other Articulata—as the lobster and crab. These animals *exuviate* or cast off their bony or hardened cases whenever their increased size demands it; and this process of moulting takes place, just like the desquamation and new formation of epidermis in man. The new shell is formed by the cells of the subjacent membrane. The casings of some of the Articulata, as the Beetle, consist of layers of epidermic cells, filled with a horny matter. The dense shells of the Crustacea are composed of similar cells filled with a substance resembling dentine, covered exteriorly with pigment cells.

The bones of the Vertebrata *grow*, just like the soft parts, by interstitial absorption and deposite; and these processes continue even after the bone

has attained the full size. This power of growth is not so much required from the waste occasioned by decomposition, as for the reparative process in case of any injury.

The conversion of cartilage into bone commences at minute points called *puncta ossificationis.* These are made by a development of canals containing vessels at certain spots. There is usually one for the shaft of each long bone,—placed near its centre; and one in each of its epiphyses. The flat bones have one about their centre, and one in each of their larger processes.

The parts of a bone, having distinct centres of ossification, do not connect together till a late period; sometimes they always remain distinct. This is remarkably the case in some of the lower animals, —as seen in their vertebræ, and in the bones of the cranium.

Before any ossific deposite occurs, the cartilaginous cells begin to arrange themselves in long rows corresponding with the axis of the bone. These rows are still separated by means of the intercellular substance. The first bony matter is deposited in the intercellular substance, by which deep cups of bone are formed, holding the cartilaginous cells. This may be called the *first* stage of the process. The next stage consists in a transformation of the cells into bone. These at first become flattened against the bony shelves, and then absorb into their cavity the calcareous matter. They also coalesce together so completely as to remove the appearance of cel-

lular structure. The nuclei of the cells, however, remain enclosed in the solid matter, thus forming cavities or *lacunæ*, which are the *Purkingean bodies*. The *canals of Havers* are formed from the bony canals containing the cartilaginous cells.

Thus, one layer after another is converted into bone, until the whole becomes ossified. During this process, there is a *blastema* deposited in the cancelli and canals: from this the vascular lining of these canals appears to be formed. This lining is the source of the future growth and reparation of the bones. From this blastema also originate the fat-cells which secrete the marrow.

The progressive growth of bone is accomplished both by superficial and interstitial deposite of osseous matter. Long bones increase in length chiefly by addition to their extremities, as is proved by inserting shot in the shaft of a growing bone; the distance between the shot remaining the same after the bone has attained its full size. The increase in thickness also takes place chiefly by external osseous deposite;—which is the cause of the *lamellated* appearance of bones.

The *interstitial* change is chiefly seen in the formation of the medullary canal. Originally, in very young animals, this cavity does not exist, its place being occupied by small cancelli; these gradually enlarge until they coalesce with one another, so as to form a continuous tube. During this process, the shaft of the bone surrounding the medullary canal, also increases in thickness by interstitial

growth; successive layers of cells being formed within those that preceded them, by which the latter are pushed outwards, and then the cancelli become increased in size beyond the limits marked out in the intercellular substance. This mode of arrangement for the shaft of the bone is proved, on mechanical principles, to be the strongest that could be devised.

The difference in the rapidity of the growth and nutrition of bones, is well seen by feeding an animal on madder, which has a peculiar affinity for phosphate of lime. The rapidity of the colouring of the bone is inversely to the age of the animal.

The process of regeneration of bone is very complete. Both the external and internal *periosteum* are concerned in it, though, properly speaking, the real production of new tissue is due to the bony spiculæ adhering to the periosteum. Thus it is found in comminuted fractures, that each fragment of bone, in connexion with the vascular membrane, becomes the centre of new osseous formation; and that the reparative process is rapid in proportion to the number of these centres.

When a bone is fractured, organizable lymph is thrown out, not only from the vessels of the bone, but from all the neighbouring parts. This becomes vascular, and is converted successively into cartilage and bone, and is termed *callus*. When the extremities of a fractured bone are brought together, it is found that ossification of the new matter commences at the centre, where the ends of the medul-

lary cavities come together, forming a sort of plug, which enters each end. This is termed, by Dupuytren, the *provisional callus*, and is generally formed in five or six weeks after the fracture. The formation of the permanent callus, which unites the bony edges together, occupies several months, during which the provisional callus is gradually absorbed, so as to restore the continuity of the medullary canal. The permanent callus has all the characteristics of true bone.

Necrosis, or death of the bone, results from extensive injury to either of the membranes. When this occurs, the reparative process commences on the part which is sound,—the external membrane, throwing out new matter on its *interior;* or the internal membrane doing the same on its *exterior.* If the whole bone is necrosed, reparation can only occur from the living bone at the two extremities, and must, consequently, be extremely slow.

II. *Of the Teeth.* The Teeth, though resembling bone in their structure, have a different origin; commencing in papillæ of the mucous membrane of the jaw. The substance of these papillæ is composed of spherical cells imbedded in a gelatinous substance, resembling that of a forming cartilage. The surface of these papillæ is composed of a dense membrane. A small arterial branch is distributed to each papilla, and spreads out into a tuft at its base. The papilla enlarges by the formation of new cells, the materials for their growth being supplied by

the blood vessels,—and when it has reached its full size, the process of solidification commences, by the deposite of dentine in the cells.

The teeth of man, and the higher animals, consist of three very different elements, the dentine or ivory, the enamel, and the cementum.

The *Dentine* or *Ivory* contains more calcareous matter than exists in bones; it amounts to 72 parts in 100. Of this, $64\frac{1}{2}$ parts consist of phosphate of lime; $5\frac{1}{2}$ parts of carbonate of lime; and the remainder of phosphate of soda and magnesia, with chloride of sodium. When viewed by the microscope, dentine is found to be traversed with minute tubuli, which appear like dark lines close together, running in a wavy direction from the cavity of the tooth towards its surface. They sometimes give off lateral branches. The diameter of even the largest of these tubuli is very much smaller than that of the blood-corpuscles; hence they probably absorb nutriment, like the canaliculi of bone, from the vascular surface.

The central portion of the tooth is hollow, and is occupied with the remains of the *pulp*. This cavity is lined by a vascular membrane, and is continued through each fang or root. From these cavities the dental tubes radiate towards the circumference. This central canal is very analogous to the Haversian canal of the bones. In some of the lower animals, instead of a cavity, we find a net-work of canals extending throughout, and communicating with the Haversian canals of the jaw.

The mode of conversion of the cells of the dental papilla into dentine, very much resembles the formation of bone. The cells arrange themselves in lines or rows, extending from the inner part to the circumference. These gradually secrete the calcareous matter, at the same time approximating together. The minute tubuli are due to the nuclei of the cells not being filled up, just as in the case of the canaliculi of the bones. Although the coalescence of the cells in the teeth of man is very complete, still, traces of them may be seen by the microscope. The dentine of man and of mammalia is not permeated by blood-vessels; but in some of the lower animals there are canals,—prolongations of the central cavity,—which transmit vessels, as is seen in bones. The central pulp sometimes becomes ossified,—usually the result of age. The *nutrition* of dentine is accomplished like that of bone. It is most rapid in the young, as seen by feeding animals on madder; a prolonged use of it being requisite to affect adults.

Where the teeth consist only of dentine, the process of consolidation of the papillæ is very simple. Sometimes a tooth thus formed remains merely attached to the mucous membrane of the jaw, as in the shark, and is liable to be torn off; but they are easily reproduced, as the development of the papillæ appears to be unlimited.

The *Enamel* is the hard covering upon the exposed portion of the teeth. It is composed of long prismatic cells of a hexagonal shape—arranged close

together, and presenting their ends to the surface of the tooth. Their diameter is about the 1-5600th of an inch. The course of the prismatic cells is wavy, and is marked by striæ. There is no appearance of tubuli or vessels. Enamel contains only two parts of animal matter, in a hundred; of the remainder, there are 88½ parts phosphate of lime, 8 of carbonate of lime, and 1½ of phosphate of magnesia.

It is by far the hardest and most dense of organized tissues, and resembles mineral substances. In man and the carnivora, it covers the crown of the tooth only; but in most of the herbivoræ it forms a series of alternate plates with the cementum, which dip down into the dentine, presenting the edges at the triturating surfaces of the tooth, so as to form an uneven surface. The enamel is more frequently absent than the other dental tissues.

The *Cementum* or *Crusta Petrosa* covers the root or fang of the tooth. It has all the characters of true bone. It is liable to hypertrophy, from inflammation, and in this way exostoses may form upon the root, rendering it difficult to extract. In the very young tooth, the cementum covers the crown also, but being very thin, it soon wears off, leaving the enamel exposed.

The primitive papilla of the tooth is originally enclosed within a capsule. Between the capsule and the papilla a sort of epithelium is developed, which becomes the enamel by subsequent calcification. The cementum is formed by the capsule itself becoming converted into bone.

The dental papillæ first appear about the seventh week of embryonic life, in the form of little prominences upon the mucous membrane of "the primitive dental groove," which runs along the edge of the jaw. About the tenth week the edges of this groove begin to send out processes which approach each other, so as to form a series of follicles. These follicles are completed by the thirteenth week, when the papillæ have attained such a size as to protrude from the mouth of the follicles. By the fourteenth week the two edges of the dental groove have met over the follicles, so as to enclose each papilla in a distinct capsule. Soon after the closure of the follicles, the formation of dentine commences by the solidification of the cells of the original papilla. Before this takes place, however, provision is made for the production of the second or permanent teeth, whose capsules are only buds or offsets from the upper part of the capsules of the deciduous teeth. At first these capsules are open follicles communicating with the others, but they are gradually closed in, and finally, entirely detached from them.

Whilst the dental papilla is undergoing conversion into dentine, its follicle increases in size, so that a space is formed between its inner surface and the papilla; this space is occupied by a gelatinous matter called the *enamel-pulp;* but it is only a thin layer of this which is converted into enamel, the remainder being removed.

Thus we have three stages in the development of the human tooth—the *papillary*, the *follicular*, and the *saccular*. Besides these, there is also the *eruptive* stage, which consists in the tooth bursting through its capsule by its growth from the root; by the same process it also penetrates the gum. The pressure of the tooth upon the nerves of the gum, is often the source of great disturbance of the health during dentition. The best remedy is free scarification of the gum.

The deciduous or milk-teeth number *ten* for each jaw; the second or permanent teeth amount to *sixteen* in each jaw. The first permanent molar is formed precisely like the milk-teeth, but it is not completed till a later period. It is in fact a true milk-tooth, so far as its formation is concerned. The second permanent molars are formed as offsets or buds from the first; and at a still later period, the capsules of the third permanent molars, or *dentes sapientiæ*, are formed as offsets from those of the second. The last are not usually developed until maturity.

The following is the average time at which the temporary and permanent teeth make their appearance:—

Temporary or Deciduous Teeth.

	Months.
Central Incisors, - - -	7
Lateral Incisors, - - -	8—10
Anterior Molars, - - -	12—13

Canines - - - -	14—20
Posterior Molars - - -	18—31

Permanent Teeth.

	Years.
First Molar - - - - -	$6\frac{1}{2}$ to 7
Central Incisors - - -	7—8
Lateral Incisors - - -	8—9
First Bicuspid - - -	9—10
Second Bicuspid - - -	10—11
Canines - - - -	12—$12\frac{1}{2}$
Second Molars - - - -	$12\frac{1}{2}$—14
Third Molars - - -	16—30

The teeth are to be considered rather as a part of the *external* or dermo-skeleton, than of the *internal* or osseous-skeleton.

The *Hair* is produced much in the same manner as the teeth,—from a pulp enclosed in a follicle. The hair-follicle is formed by an inversion of the skin, just as the tooth-follicle is made by an inversion of mucous membrane; and it is lined by a continuation of the epidermis. At the bottom of the follicle there is a papilla composed of cells; the exterior of this is called the *bulb*, and the interior, being soft, is named the *pulp*. The follicle is very vascular.

It was formerly supposed that the hair was a mere horny secretion from the pulp. The microscope shows it to consist of two distinct portions, a *cortical* part, of a horny fibrous nature, and a *medullary* or internal portion. These distinctions

are best seen in the bristles of the hedgehog, and the quills of the porcupine, which are only enlarged hairs. The cortical portion gives firmness to the hair. The medullary substance consists of an aggregation of large cells, the contents of which are not fluid. In the human hair, the greater part is made up of the horny cortical portion, which is fibrous.

The hairs are invested with very minute scales, like those of the epidermis, arranged in rows overlapping one another, which gives the appearance of delicate lines on the surface. The colouring matter of the hair seems to be owing, in part at least, to iron, and it resembles hæmatin. It is more abundant in dark than in light hair. The fibres of the cortical substance of the hairs are believed to be made up of cells altered so as to assume the elongated form, and which have secreted the horny matter into their interior. The medullary matter is probably developed from the cells of the pulp. Thus the hairs grow from the base, just as the teeth of some animals grow from persistent pulps. When thus formed, the hair is not very liable to undergo change, but occasionally it is affected with changes at its base;—thus violent mental emotion has been known to turn it gray in a single night; this must have been owing to the secretion of a fluid at the base, capable of affecting the colour, transmitted through the medullary portion. A similar power of imbibition is seen in the disease termed *Plica*

Polonica,—where drops of blood also have been said to exude from the cut extremities of the hairs.

Sect. 5. *Cells coalesced into Tubes with secondary deposite.*

The tissues which are composed of cells coalesced into tubes, are the *muscular* and *nervous;* both of which are peculiar to animals.

1. *Of Muscular Tissue.* A muscle, when examined by the naked eye, is found to consist of *fasciculi*, or bundles of fibres arranged together with great regularity in the direction in which the muscle is to act. These bundles are connected together by means of areolar tissue. The fibres of these fasciculi are seen by the microscope, to be each made up of a number of minute fibres bound together by delicate areolar tissue. These last are the *ultimate* muscular fibres.

Ultimate muscular fibre is presented under two forms:—the *striated*, and the *non-striated.* The striated form is found in the voluntary muscles, or the muscles of animal life; the non-striated, in the muscles of organic life. The striated muscular fibre presents the appearance, either of very delicate *fibrillæ*, by its splitting up in the longitudinal direction, or of a series of *discs*, by its separating in a transverse direction. The real composition of the fibre appears to be of flattened disk-like cells of uniform size. These are adherent both by their flat surfaces, and by their edges. The former adhesion

being usually the most powerful, causes the fibre, when broken up, to present the appearance of *fibrillæ*, each of which is composed of a single *row* of the primitive particles. But when the lateral adhesion is the stronger, the clearage is crosswise—in the form of *disks*,—each of which is composed of a *layer* of primitive particles.

The muscular fibre is covered by a very delicate tubular sheath, called the *Myolemma* or *Sarcolemma*. This cannot always be distinguished on account of its transparency, but it is made evident by drawing the ends of a fibre apart, when its contents will sometimes separate without a rupture of the sheath. It may also at times be seen rising in wrinkles, on the surface of the fibre, when the latter is in a state of contraction. It may also be made evident by subjecting muscular fibre to the action of acids or alkalies, which make the contents swell up, so as to burst open the myolemma in spots, and cause a sort of hernial protrusion of the contents. This membrane is not perforated, either by nerves or blood-vessels; in fact, it forms a barrier between its contents and the surrounding parts.

Muscular fibres, though commonly described as cylindrical, are really polygonal,—resulting from pressure; the angles are sometimes rounded off so as to afford space for the passage of vessels. The size of the fibres varies considerably, not merely in different animals, but in different sexes, and even in different muscles of the same animal. In the human

male the average size, according to Bowman, is 1-352d of an inch; in the female, 1-454th of an inch. The average size in reptiles and fishes is greater than in mammalia, but the extremes are much wider.

When the ultimate *fibrillæ* of the fibres are examined by a very high power, they are observed to present a beaded form, and to be made up of a linear aggregation of distinct cells, presenting an alternation of light and dark spaces. There is also a light border around the dark spaces, as well as between them. This transparent border appears to be the cell-wall; the dark space within this, is the cavity of the cell filled with a refracting substance. When the fibril is relaxed, the cells assume an oblong shape, the greatest diameter being in the longitudinal direction; when the fibril is contracted, the transverse diameter of each cell is increased, so that the dark spaces become square, or their transverse diameter may even *exceed* their longitudinal one. Thus, it seems that muscular contraction consists essentially in an alteration in the form of the ultimate cells, arising from an attraction between their opposite walls. This closely resembles the contraction of vegetable tissues, whose component cells, when irritated, undergo a change of form, causing movement. The essential difference between the two is, that muscular tissue is under *nervous* influence.

The diameter of the ultimate fibrillæ is tolerably

uniform in different animals—being about 1-10,000th of an inch. It has been computed that the human muscular fibre contains from five to eight hundred fibrillæ; it varies, however, according as it is contracted or enlarged. The average distance of the *striæ*, also, is about 1-10,000th of an inch; but it is also subject to variations.

The muscular fibre of *organic* life, (the involuntary muscles,) is the non-striated. It consists of a number of filaments, which are tubular, like the preceding; their contents being granular, but without any definite arrangement into fibrils or disks, as in the former. The size is usually much less than that of the striated fibre. It is difficult to estimate their dimensions, owing to the variations in the degree of flattening which they undergo; from 1-2500th, to 1-5600th of an inch is about their average diameter. They have a knotty appearance, which is due to the remaining nuclei of the formative cells. These muscular fibres, like the others, are collected into fasciculi or bundles, but these fasciculi are generally interwoven into a network without having any fixed point of attachment.

This is the kind of muscular structure which is found in the stomach, intestinal canal, œsophagus, bladder, the pregnant uterus, also in the trachea and bronchial tubes, but not in the pharyngeal muscles. The heart contains a mixture of the striated and non-striated fibres. The middle coat of the arteries contains a modification of the non-striated variety.

9

The latter is also found in the skin, occasioning by its contraction the appearance called *cutis anserina;* also in the dartos, causing the wrinkling of the scrotum.

In the development of muscular fibre, the myolemma or tubular sheath is first formed,—from cells uniting in a row, the intervening walls being broken down. The nuclei of the original cells sometimes remain, and may be seen projecting from the sides of the fibre. These projections are not so perceptible in the muscles of animal life, unless the fibre be treated with dilute acid which brings them into view by rendering the nuclei more opaque. It is highly probable that these nuclei continue to furnish the cells that compose the fibrillæ. Thus, it is found that the diameter of the muscular fibre of the fœtus is only one-third that of the adult; but as the size of the *ultimate particles* is the same in both, the growth can only take place by an increase in their *number*. Besides, every exertion of muscular power is attended with a decay of its particles, which must be made up by a regeneration of new structure. And this is probably accomplished by these nuclei, out of the blood which circulates in the muscle. Hence we see there is no difference in the early development of the striated and non-striated muscular fibre; but while the former continues on till fibrillæ are produced, the latter stops short of this.

The *vascularity* of muscles is very great. Though the ultimate muscular structure is not in actual contact with the blood, the capillaries are abundantly

distributed through the spaces between the fibres. In this way their nutrition is accomplished; the arterial blood affording the materials of growth, while the venous carries off the effete products of disintegration; and this is probably accomplished, as before stated, by *cell-absorption*.

The power of muscular action depends upon the oxygen conveyed to the muscle by the arterial blood. Warm-blooded animals soon lose this power, if the supply of arterial blood is cut off;—cold-blooded animals not so soon.

Nerves are more abundantly distributed to muscles of animal life, than to any other tissue, except the skin. They do not penetrate the myolemma, but lie on the outside, like the capillaries. They do not, properly speaking, *terminate* in the muscle, since their ultimate fibres form loops, which either return to their original trunk, or else form a connexion with another. The muscles of organic life, (non-striated) are sparingly supplied with nerves: and these are chiefly derived from the sympathetic.

Every striated muscular fibre is attached by its extremities to fibrous tissue, the sum total of which, in any muscle, constitutes its *tendon*. The muscular fibre terminates abruptly by a perfect disk; the tendinous fibre being attached to the whole surface of this disk, and becoming continuous with the myolemma. Sometimes the muscular fibres are inserted obliquely into a tendinous band, as in the case of the *penniform* muscles.

The various forms of muscles have reference solely, to the mechanical purposes they are to accomplish: the *elements* of all are alike.

The composition of muscle seems to be nearly identical with the fibrin of the blood. It cannot be perfectly analyzed, owing to the impossibility of separating the areolar tissue, vessels, nerves, &c., from it. The solid matter forms about 23 parts in 100; the remainder being water. Of the solid matter, about $7\frac{1}{2}$ per cent. consists of fixed salts. It is doubtful whether muscular tissue is ever regenerated, where there is an actual loss of substance. Wounds quickly heal through the intervention of areolar tissue, which becomes consolidated, but never exhibits the power of contractility.

The characteristic of muscular tissue is the power of *contractility* under a stimulus. This is also seen in certain vegetables, as the sensitive plant, &c., and results, in them, from the contraction of their cells. The simplest form of muscular contractility—that of the muscles of organic life,—closely resembles that seen in plants; thus the non-striated fibre contracts most readily by a stimulus applied directly to itself. The *striated* fibre, on the contrary, is more readily affected by a stimulus acting through the nerves supplying it. Muscular contractility is often spoken of under the heads of *irritability*, or the property of alternate contraction and relaxation, and *tonicity*, or a moderate and permanent contraction. Haller's doctrine that con-

tractility is an *inherent* property of muscular tissue is believed to be correct. It is proved not to depend on the nerves, from the fact that a muscle, or even a single fibre, may be made to contract under a stimulus, when the nerves supplying it have been divided. Besides, the non-striated fibre can scarcely be made to contract through the nerves, while a *direct* stimulus will cause immediate action.

The reason why division of the nerves, or paralysis, will be followed by a loss of muscular contractility, is because the *nutrition* of the muscle is impaired by its want of use; the muscles of animal life being called into action usually through the medium of the nerves. For the same reason, we see the wasting away of muscles which are not used. Dr. Reid's experiment proves this: he divided the sciatic nerve on both sides of a frog, and applied a moderate stimulus by means of galvanism to the limb of *one* side for two months, leaving the other limb untouched; at the end of that time, the muscles of the former were found unaltered in their nutrition and power of contracting, while those of the latter had wasted away and lost some of their contractility. This also explains the fact that in cerebral palsy, the irritability of the muscles remains unaffected, because they may still be called into action through the reflex system of *spinal* nerves. Muscular contraction is excited most powerfully by electricity; but heat, cold, chemical agents, or even mere contact, will also act as stimuli. The effect

of the stimulus will depend upon the kind of muscle acted upon; thus, in a *voluntary* muscle, only the fasciculus of fibres irritated will contract, the rest of the muscle being unaffected, and relaxation will soon follow. But if a portion of *non-striated* fibre be irritated, as in the alimentary canal, the contraction will be less sudden, but will propagate itself to other portions successively, and the relaxation will be less speedy.

If a nerve supplying a voluntary muscle be irritated, every portion of it is simultaneously affected. The ordinary actions of the voluntary muscles are executed through the channel of the nerves; and these nerves are derived either from the brain or spinal marrow. The ordinary actions of the non-striated muscles are caused by *direct* stimuli; indeed it is very difficult to excite contractions in them through the medium of the nerves. The sympathetic nerve chiefly supplies the non-striated muscles; but it is believed that the *motor* power in these is derived from the branches of the cerebro-spinal system which are united with the true sympathetic.

When a muscle contracts, its *bulk* is not affected. It is shortened in the direction of its fibres, but its diameter is proportionally enlarged. It was formerly supposed that the ultimate fibres threw themselves into zigzag folds in contracting, but this has been disproved; each fibre shortens in a straight line. The striæ of the fibre approach each other more closely, in consequence of the approximation of the light and dark spaces of the individual fibrillæ.

Bowman says that the contraction usually commences at the extremities of a fibre. The first appearance of it is a dark spot caused by the approximation of the striæ, and this forces out the fluid that was previously among the interstices of the fibrillæ, so as to cause the appearance of little vesicles beneath the myolemma, which is drawn up in wrinkles.

When the ear is applied over a muscle in a state of vigorous contraction, a peculiar faint and rapid sound is heard, caused by the constant movement in its substance. This arises from the fact that the whole of the fibres are not in a state of contraction at once, but while some are passing from a relaxed to a contracted state, others are doing the reverse. Hence, although it is true, that in individual fibres contraction is speedily followed by relaxation, still the contraction of the *whole muscle* may be much prolonged.—The occasional zigzag appearance of the fibres may be accounted for by the approximation of their extremities, in consequence of the contraction of some neighbouring fibres, while their own condition is that of relaxation.—In the heart, the whole of the fibres contract together, and relax simultaneously.

The essential condition for the manifestation of muscular contractility, is the abundant supply of oxygenated blood. The length of time during which the contractility remains after the circulation has ceased, is inversely to the activity of the respiration of the animal, (Hall;) thus in cold-blooded animals,

it lasts much longer than in the warm-blooded. In man, the contractility of the several muscular tissues is lost in the following order after death:—the left ventricle first; the intestinal canal in about 50 minutes; the œsophagus in an hour and a half; the iris rather later, and last the auricles, especially the right.

The following experiments prove the necessity of oxygen in the circulating blood:—If the brain and spinal cord be removed, provided artificial respiration be kept up, the muscles will preserve their irritability; if the general circulation continue, and that of a particular muscle be cut off, that muscle will lose its irritability; if an animal be made to breathe carbonic acid, the muscles lose their irritability as soon as death takes place. In fact, the loss of the power in the heart to contract, from the presence of venous blood, is one of the immediate causes of death. If an animal be made to breathe oxygen, the contractility of the muscles is retained for a longer time than usual.

The contractile power of a muscle is greatest when it is stretched to its full length, and not, as was supposed, when it is partially contracted. This was proved by Schwann, by attaching a delicate balance to the sartorius of the frog; the power of sustaining a weight, progressively diminished as the muscle shortened. Hence the inference that the *power* which causes muscular contractility must differ from galvanism, or any other force of attraction known to us, since all these forces increase in

energy, as the attracted parts approach each other inversely as the square of the distance; but muscular force, as shown above, appears to act in the *direct ratio of the distance.*

During muscular action the temperature slightly rises,—from one to two degrees. This may depend both upon the chemical changes which are then taking place, and upon the friction between the particles.

In proportion to the energy of muscular action, must be the amount of its nutrition, and of the supply of arterial blood. But it is well known, from the increased quantity of solid excretions that occur during muscular exertion, that there must be a correspondent degree of waste or disintegration of the muscular tissue. The products of this waste consist of the elements of muscular fibre in union with oxygen; these are carried off by the venous blood; and the loss is supplied, or the nutrition is kept up, by the fibrin of the arterial blood.

Some of the muscles are in *constant* action, as the heart, and the muscles of respiration; here the reparative process must be as constant as the waste; such muscles never experience *fatigue.* It is different with the voluntary muscles; the fatigue occasioned by a prolonged action is an evidence of their impaired condition; and rest is required to allow the process of nutrition to go on. The effect of continual moderate exercise of a muscle, is to increase its size, by increasing its nutrition: this occurs both to the voluntary and involuntary muscles.

The *Tonicity* of a muscle is that constant tendency to contraction, which is seen in every living muscle. It is shown by the retraction which occurs in the end of a muscle when divided. In health, the tonicity of the different muscles is about balanced, but in paralysis of the extensors, there is permanant flexure of the joints, arising from the tonicity of the flexors; this is seen in lead-palsy. The tonicity is proportionally greater in the non-striated than in the striated muscular fibre; it is particularly evident in the arteries, causing their contraction when they are emptied of their contents. It is also greatly affected by temperature, being increased by cold, and diminished by warmth.

The stiffening of the body after death, called *rigor mortis*, is believed to be due to the tonicity of the muscles, occurring after all irritability has departed, and before putrefaction has commenced. This rigidity is scarcely ever absent, though it may be very slight and of short duration. It does not always commence at the same period after death. When the system, at death, is much weakened or depressed, as in typhus fever, the stiffening comes on early and lasts but a short time; but when death has suddenly occurred in a vigorous person, the *irritability* of the muscles continues longer, and the rigidity is deferred. It usually commences about seven hours after death, and lasts from twenty-four to thirty-six hours; the flexors are rather more affected than the extensors. The non-striated fibre is more affected than the striated,—particularly the heart and arteries.

The rigor mortis is the last act of muscular contractility; as soon as it ceases, the muscles begin to putrefy. By some, it has been attributed to the mere coagulation of blood in the muscles. Bowman has disproved this. Still there are many points of resemblance between the two.

The mechanical application of muscular power in animals is usually unfavourable as regards *force*, but very advantageous as respects the *space* moved over. This is seen particularly in the flexors of the forearm and leg.

Of all animals, muscular power seems to be greatest in Insects, particularly in the beetle tribe.

The *rapidity* of muscular movements is seen in the pulsations of the heart, in the human voice, and in the vibrations of the wings of insects.

Muscles are far less sensitive to external impression than other parts of the body. This is seen in amputations, where the greatest pain is occasioned in cutting through the skin, the muscles suffering comparatively little.

II. *Nervous Tissue.*—The possession of a *nervous system* may be regarded as the characteristic point of distinction between animals and vegetables. Although there are certain plants which exhibit properties very analogous to what is denominated *sensation*, still these are clearly proved to be merely the result of irritability, which can be shown to be an entirely different property from sensibility, which belongs exclusively to animals. Wherever a nervous system can be made out, it

is found to consist of two distinct elements; these are the *ganglia* or centres, and the *nerve-trunks* or conductors. The ganglia are sometimes mere enlargements in the course of the trunks, and sometimes distinct central masses giving origin to the trunks. The functions of these two portions are very distinct; the ganglia originate, or send out the nerve influence; the trunks merely serve as conductors of this influence. These will be considered separately.

1. The Nerves or nervous trunks consist, each, of a bundle of fibres enclosed in a common delicate sheath, composed of white fibrous matter and named *neurilemma*. From the interior of this sheath numerous processes pass down between the different fibres of the trunk, separating them into smaller fasciculi, but at the same time binding them together, and, as in the case of muscular fibre, serving to transmit the nutrient capillaries. The fasciculi of nerves may be still farther divided into the *ultimate nerve-fibres*, which are the elementary forms of nerve structure. Two forms of ultimate nerve-fibre exist in the higher animals, analogous to the two forms of muscular fibre; one appearing to be the instrument of the *animal* functions; the other, which is less perfectly formed, being connected with the *organic* functions. The former of these is distinctly tubular, having a very delicate membranous covering resembling the myolemma of the ultimate muscular fibre. This membranous tube is not penetrated by blood vessels, but serves, like the

myolemma, completely to insulate the contents; and it is believed to be continuous from one end of the nervous trunk to the other. Within this tube is another hollow cylinder of a material known as the *white substance of Schwann*, which differs in its properties from the axis of the tube; this latter is a transparent substance, and is called the *axis cylinder*. This latter portion is believed to be the *essential* part of the nerve structure. The whole contents of the tubular sheath are extremely soft, and readily yield to pressure, and the sheath itself varies in density in different parts, being stronger in the nervous cords than in the brain and spinal marrow. It is on account of the greater delicacy of the tubular sheath in the latter, and in the nerves of special sense, that the slightest pressure causes the contents to assume a varicose or beaded appearance, which was deemed by Ehrenberg, who first noticed it, to be characteristic of them. The diameter of the ultimate tubuli varies from the 1-14,000th, to the 1-1500th of an inch; but the usual dimensions are between 1-2000th and 1-4000th of an inch. The largest are found in the nerve-trunks;—in the brain they diminish as they approach the cortical portion.

The other variety of nerve fibres is termed the *organic* or *gray*. They are chiefly found in the sympathetic system, and are named *gelatinous* by Henle. They do not appear to consist of the same variety of elements as the former, since no tubular sheath, nor white matter of Schwann can be distinguished. They have a homogeneous appearance, and resemble

the non-striated muscular fibre in containing numerous *cell-nuclei.* These may be made to appear by the action of acetic acid, which dissolves the rest of the fibre, leaving them unchanged. The diameter of the organic fibres is usually less than that of the others; it averages, from the 1–6000th, to the 1–4000th of an inch. The term *gray* fibres is derived from their yellowish-gray colour.

Both classes of fibres run continuously from the beginning to the end of the nerve, without anastomosing with each other;—the probability being, that each ultimate fibre has its own distinct office. The *fasciculi* or bundles of fibres occasionally anastomose with each other; and this may occur either among the fasciculi of the same trunk, or among those of different trunks. The object of such an interchange, is evidently to impress upon the different branches the peculiar endowments of any one set of fibres. It is by this means that every branch of the spinal nerves which arises from two distinct sets of roots, is furnished with both sensory and motor fibres. In the same way, some of the cephalic nerves, which arise exclusively either from motor or sensory roots, acquire the functions of the other; and the same union is observed between the sympathetic, which arises from a number of distinct ganglia, and the cerebro-spinal system, which arises from the brain and the spinal marrow.

A *plexus* of nerves is the union of the fasciculi of several distinct trunks, for the purpose of a more advantageous distribution. Thus the brachial plexus

is composed of the fibres of five pair of spinal nerves; it sends off five distinct trunks to supply the arm, each trunk, of course, containing fibres from every one of the five spinal nerves. By this arrangement, the liability to paralysis is much diminished, since the functions of the *whole five* segments of the spinal cord must be suspended before any one part of the arm could be affected. A nerve-plexus may also contribute to a *consentaneousness* of movements.

2. The second element of the nerve structure is known by the name of *vesicular*, *cellular*, *cineritious* or *gray* substance. It differs entirely from the fibrous or tubular portion, being composed of nucleated cells containing a fine granular substance, and lying somewhat loosely in a minute plexus of blood-vessels. The normal form of these cells is globular, hence they have been termed *nerve* or *ganglion-globules;* but they may become oval or polygonal by pressure. They may also be observed to have one or more processes or peduncles extending from them, giving to them a caudate or stellate appearance. According to Todd and Bowman, who have particularly examined them, these processes are composed of a granular matter resembling the interior of the cell, with which they seem to be continuous. These peduncles may be traced some distance from the cell, when they are found to subdivide, and also to inosculate with those of other stellate cells; and it is surmised that they may become continuous with the axis-cylinders of the nerve tubes. The

diameter of these globules or cells is between the 1-3000th and 1-2500th of an inch. They also contain, especially in the higher animals, some *pigment-granules*, which give them a reddish or grayish colour, hence the name *cineritious*. Sometimes each of these cells or vesicles is enclosed in a distinct envelope composed of smaller cells closely adherent to each other and to the contained cell; this arrangement is found in the inner portion of the cortical substance of the brain.

The vesicular or cineritious substance is found in the centre of the different ganglia, in the interior of the spinal cord of the Vertebrata, and on the exterior of the brain, forming its *cortical* position; and likewise upon those parts of the surface or *periphery* which are destined to receive impressions, as in the expansion of the optic nerve or retina, which contains a distinct layer of nerve-globules,—also upon the expansions of the olfactory and auditory nerves, and probably upon the papillæ of the tongue and skin. It may be distinguished, in man and in the higher animals, from the *tubular* or white portion, by its colour; but this is not an invariable distinction, since the pigment-granules and red blood, to which the dark colour is due, are wanting in the Invertebrata and some others; besides, the gray colour, as we have already seen, belongs also to the organic nerve-*fibres*. The *real* distinction between them consists in their elementary form,—the one being fibrous and the other vesicular.

The first developement of the *fibrous* portion of

nervous structure seems to take place, like muscular fibre, by a coalescence of a number of primary cells into a tube; the nuclei of these cells may often be seen between the walls of the membrane and its contents. The nerve-tubes probably undergo but little subsequent change.

The *vesicular* structure seems to be produced and regenerated by a continued succession of cells, like those of the epithelium. Henle supposes that in the cortical portion of the brain, this continued development is going on from the surface towards the centre,—the cells being formed on the surface and carried *inwards*, just as the epidermic cells are carried progressively *outwards*.

The mode of connexion between the fibrous and vesicular portions of nerve structure is not clearly made out. Mr. Newport has shown that nerve-fibres may enter a ganglion, and come in contact with its vesicles—and then pass out again. The same appears to be the case with some of the fibres that enter the vesicular matter of the brain and spinal marrow. There is a strong probability that the nerve fibres form *loops* in the vesicular matter; hence, they cannot properly be said to have either origin or termination. This is undoubtedly the case with the fibres entering the *peripheric* vesicular matter, as the skin. The view, however, taken by Todd and Bowman, would incline to the belief that *some* of the fibres may originate directly from the granular prolongations of the nerve-cells.

Chemical composition of Nerve structure. The proportion of solid to fluid matter is from one-fourth to an eighth of the entire weight. The quantity of water is greatest in infancy, and least in middle life, and is said to be less than the average, in idiots. Of the solid matter of the brain, about a third consists of albumen or fibrin, of which probably the sheath of the tubuli is composed. Another third is composed of fatty matter which contains, besides common fat and cholesterin or biliary fat, two peculiar fat acids, called cerebric and oleo-phosphoric. Cerebric acid is white and crystalline; it differs from common fats in containing nitrogen, and double their amount of oxygen, with a small portion of phosphorus. Oleo-phosphoric acid is of a viscid consistence, and is separated from the other by ether; when boiled for a long time in water or alcohol it loses its viscidity, and becomes converted into elaine and phosphoric acid. The whole amount of phosphorus in the brain is eight to ten parts in a thousand, or from one-twentieth to one-thirtieth of the solid matter: it is usually deficient in the brains of idiots. The remaining third consists of osmazome associated with saline matter. No satisfactory information has been obtained as to the comparative composition of the two kinds of nerve substance; but the vesicular is stated to contain rather more water than the fibrous, and some red fat which is not found in the other.

There is every reason to believe that nervous structure, like the other tissues of the body, is con-

tinually undergoing the processes of decay and renovation; and that its waste and disintegration are in exact proportion to the activity of its *functions.* By an unusual demand upon the nervous powers, especially upon the brain,—the organ through which the mind acts,—a sense of fatigue is experienced, and the necessity for repose or sleep arises, during which nutrition goes on without interruption, and the organ recovers its usual strength. The actual amount of sleep required to restore the nervous system to its normal condition varies in different persons, on account of some difference in constitution; and where, by an effort of the will, the brain is *forced* to a prolonged exertion, and the natural tendency to sleep resisted, both the bodily and mental health will give way, from the derangement in the nutrition of the organ.

The amount of waste of the nervous system is measured with considerable accuracy, by the quantity of *phosphatic deposites* in the urine; just as the waste of muscular tissue is represented by the *urea.* This belief is confirmed by the fact, that no other soft tissue contains any large amount of phosphorus, and also that any unusual demand upon the brain, either by intellectual exertion, or anxiety, is sure to be followed by an increase in the phosphatic deposites. The nutrition of nerve tissue must be very active to make up for the constant waste; hence we find it abundantly supplied with blood. This also accounts for the fact that persons of very active minds generally require nearly as much food as

those whose muscular system is more exercised, but whose mental exertions are less.

The *regeneration* of nervous tissue is usually very complete, and is familiarly seen in the restoration of motion and sensation in divided parts, and even more conclusively in the production of new nerve matter, where there has been a complete destruction of the parts. We are not so well informed as to the degree of reparation of the vesicular substance; but from the known activity of its nutritive changes, there is every reason to believe that its reparation is complete and rapid.

The consideration of the *functions* of the nervous system, and of its development in different animals, is reserved for the latter part of the work.

CHAPTER V.

OF DIGESTION AND FOOD.

Sect. 1. *Of Food, and the Sources of its demand in Animals.*

All organized beings are dependent upon a due supply of aliment or food. In the very earliest states of the new being, this aliment is prepared by the parent; thus, in the seed, the germ occupies but a very small portion, the great bulk being made up of starchy matter designed for nutriment. The same is true of the egg of the animal, the chief portion of which consists of albumen and oily matter.

which the germ, in process of development, draws into itself, and uses in the construction of its various parts.

There is a difference between vegetables and animals as regards the *source* of their food. The former have the power of combining inorganic elements so as to form organic compounds; the latter must form their organic compounds from some pre-existing organized body, either animal or vegetable. Hence, animals *create* nothing; the materials for their nutrition must be already prepared. These materials may be divided into four classes:

1. The *Saccharine* group,—including those vegetable substances analogous in composition to sugar, consisting of oxygen, hydrogen and carbon, the two former in the proportion to form water;—starch, gum and lignin are examples of this class. 2. The *Oleaginous* group,—including vegetable and animal oils and fats. They are characterized by containing no nitrogen, and only a small proportion of oxygen, but an excess of carbon and hydrogen. 3. The *Albuminous* group,—comprising the protein-elements both from vegetables and animals, consisting of albumen, fibrin, casein, &c. 4. The *Gelatinous* group,—comprising such animal substances as resemble gelatin in composition.

These four groups may be comprised under the two general heads of the *azotized* and *non-azotized* products. The use of the azotized products is for the nutrition and reparation of the animal tissues. The non-azotized substances are designed chiefly to

supply the materials for animal heat and respiration, the *surplus* being deposited as fat.

Animals differ from vegetables as regards the *size* attained. In vegetables the increase may go on to an almost unlimited extent under a due supply of aliment, nearly the whole of which is appropriated to their development; but in animals the full size is soon attained, after which all the nutriment goes to repair the waste of the system. The products of this waste are seen in the excretions. Consequently the quantity of food required, will be in proportion to the activity of the animal functions; hence the difference between the man of active life, and the one of inert habits.

There is also a waste in animals from the exercise of the organic or vegetative functions, which, as has been shown, are accomplished by means of cell-growth. This waste, however, is far less than that occasioned by the exercise of the animal functions, as in the nervous and muscular tissues.

Another cause of the demand for food is the maintenance of animal heat. This process being the result of the combustion of the carbon and hydrogen of the food, with the oxygen of the air taken in during respiration, the quantity required will be, of course, much greater when the external temperature is low, than when it is high. Hence the difference in the appetite, in cold and hot weather. The demand for food is likewise dependent on *age*. The large proportional amount required during the period of growth, is not so much for the mere *increase* of the

body, as on account of the rapidity of the interstitial changes which are then taking place. The converse is true of the aged, in whom these changes are much slower; hence, in them, the demand for food is far less, in proportion to the bulk of the body, than in the adult, and often even absolutely less than in a child. Any unusual drain upon the system, will also increase the demand for food,—thus the secretion of milk, a suppurative discharge, and the discharge in diabetes.

There is also a *natural* difference in regard to rapidity of the changes of the system among different persons, producing, consequently, a difference in the amount of food required.

Variations in the food have a greater effect on vegetables than on animals, as regards their size. It is easy to *dwarf* a plant, by merely transplanting it from a rich to a poor soil, particularly if the temperature be lowered. But a similar effect is not produced upon an animal, because the corresponding diminution of food would prove fatal to it. Occasionally, however, the influence of this cause is manifested among insects,—particularly during their larva state. An *excess* of food has not the power to increase the size beyond a certain point;—as only a certain amount can be assimilated, the remainder is gotten rid of as *excretions*. The mere presence of an excess of nutritive matter in the blood, so far from conducing to health, is a source of disease. If fibrin preponderate, the tendency will be to inflammation, if the red globules,—to hemorrhage. Be-

sides this, the excretory organs, having an unnatural amount of labour to perform, are liable to become disordered; hence the frequency of disease of the liver and kidney from excess in eating and drinking.

The influence of an increased supply of food in the more complete development of an animal, is well seen in the case of the *queen-bee*, which is developed from an egg, that, under ordinary circumstances, would have become a *neuter* working-bee,—merely by the supply of a richer and more stimulating kind of food.

The only tissue that is increased directly by an excess of food, is the adipose. And this is produced almost entirely from the non-azotized articles—chiefly the oily. The formation of fat only occurs when there is an *excess* in the materials for supplying the process of respiration, and maintaining animal heat. Hence, whatever diminishes this demand for heat, is favourable to the production of fat, and vice versa. In this way cattle are readily fattened, by being kept at rest in a warm temperature, and fed on oily substances. The great object of the store of fat is for the supply of *fuel* for the maintenance of animal heat. In animals that are starved, the temperature notably sinks just before death; in fact, the immediate cause of death, in such cases, is the great reduction of temperature.

Certain individuals, as well as animals, evince a proneness to the production of fat; in others it is the reverse. These latter are apt to be of the *bilious* temperament. In them, the excess of fatty matter in food must pass out of the system through the liver,

causing a tendency to liver-disease. Here it is important to avoid a too fatty diet; or else due exercise should be practised, in order that by the additional respiration, the excess may be *burned* off.

It is impossible to lay down any general law as to the precise *quantity* of food that is requisite. The average amount, for a healthy adult man taking moderate exercise, may be stated to be from 30 to 36 ounces of dry aliment a-day; but much less may suffice.

The value of different sorts of food depends upon the quantity of *solid matter* they contain,—upon the proportion of *digestible materials* in these solid matters,—but chiefly upon the *chemical composition* of the substances; those which contain nitrogen, (the azotized,) being far more nutritious than the non-azotized. Gelatin alone cannot support life; but it is useful to repair the waste of the gelatinous tissues. If it be withheld, these tissues must be supplied by the transformation of the protein compounds. There is no proof that gelatin is ever converted into any of the protein compounds. Vegetables abound chiefly in the non-azotized products, as sugar, starch, and oil. Those which contain most of the azotized materials are the leguminous plants, which are known to be the most nutritious. The great use of the non-azotized articles, as before said, is to supply materials for respiration and animal heat. Thus, in the *saccharine*, where the oxygen and hydrogen exist just in the proportion to form water, the carbon which is set free combines with the oxygen taken in by the

lungs. In the *oily* matter there is a great excess of hydrogen and carbon, both of which combine with oxygen taken in by respiration, and contribute to supply the heat. Hence it is, that the inhabitants of the frigid zone make use of so much oil and fat in their food, by which they are enabled to sustain the extreme cold of their climate. Nearly all the saccharine matters of the food, are very soon carried off by the process of respiration, scarcely ever reaching the general circulation.

The diet best adapted to man, is one containing a due admixture of the azotized and non-azotized materials. This is just the case in *wheaten bread*, which is so universally employed. The mere *farinaceous* articles, such as rice, potatoes, &c., which contain so little protein matter, cannot properly support life, unless a large quantity be digested, and the persons lead an inactive life. The use of *meat*, to any extent, is rather injurious, unless accompanied with a very active life.

Milk contains a mixture of saccharine, albuminous and oleaginous materials, and is hence well adapted to the nutriment of the young animal. It is said that the milk of the carnivora contains no sugar.

It is impossible for an animal to be nourished upon any *single* alimentary substance, no matter how nutritive it may be, on account of the disgust which long continuance always excites. The same is true of man. This occasions a great difficulty in the treatment of diabetes, where the exclusive use of

animal food becomes so unpleasant to the patient, that he is unwilling to continue it. It has been found, that bread made from flour, deprived of all the farinaceous matter, and containing only gluten, may be used as a substitute; and also *cabbage*, which in the raw state consists almost entirely of vegetable-albumen. Certain inorganic substances are also required in the food,—as *chloride of sodium*, for the muriatic acid in digestion, and for the soda in the blood; *phosphorus* as a constituent of nerve-structure, also in the composition of bones, (phosphate of lime,) and in some of the secretions, in the form of acid and alkaline phosphate of lime and soda; *sulphur* in some of the tissues;—*lime* in bones and shells;—*iron* in the hæmatin of the red corpuscles of the blood. All these substances are found in the common articles of food: if they be withheld, the function of nutrition will be incomplete.

Sect. 2. *Varieties in the Digestive Apparatus.*

The aliment of animals differs from that of vegetables, in being required to undergo the process of *digestion*. The object of this process is threefold:—the reduction of food to a fluid form, the separation of that portion which can be absorbed from that which cannot, and a certain change which is undergone by the former to prepare it for future use.

The simplest conditions for accomplishing these purposes are,—the presence of a fluid to act as a solvent, a fluid capable of acting as a precipitant to

separate the excrementitious from the nutritive, and a cavity or *stomach*, where these processes can be performed.

In the lowest animals, as the hydra, or fresh water polype, the stomach is only an inversion of the skin, having but a single opening. The solvent fluid or *gastric juice* is secreted by the walls of this cavity, and acts upon the food when taken in; the nutritive matter is absorbed from the walls of the cavity, and the effete portion thrown out by the same orifice.

In animals a little higher in the scale, the stomach is continued into a canal, which has its appropriate exterior opening—the anus. The gastric juice is secreted as before; but *bile* begins to make its appearance, being furnished from follicles in the stomach. Still higher in the scale of animal life, the digestive organs become more complex, though never differing in their essential character; the teeth being added for mastication, and the salivary glands for insalivation.

Among higher animals, the true digestive process takes place in the stomach, the form of which varies with the character of the food. When this is of so simple a nature as easily to be acted upon by the gastric juice, the stomach is only a simple enlargement of the alimentary canal—this is the case with animals that feed chiefly upon blood, as weasels, &c. But where the food has to undergo much change, the stomach forms a considerable enlargement, as in the herbivora. In man, the form is intermediate between the two. The admixture of

the bile with the food takes place after the latter has quitted the stomach.

The intestinal canal is added for the purposes of completing the changes which the food must undergo, before all the nutritious portions can be absorbed. Its *length* corresponds with the character of the food. Thus in the carnivora, whose food is easily assimilated, it is comparatively short. In the herbivora, on the contrary, it is extremely long;—in the sheep it is twenty-eight times the length of the body. In man, whose diet is of a mixed nature, the alimentary canal is about 30 feet long, or about five or six times the length of the body.

The intestine is divided into small and large. The *small intestine*, in man, constitutes about five-sixths of the whole. Its mucous membrane is arranged into folds, called *valvulæ conniventes*, the object of which is to extend this surface for the increased lacteal absorption, by means of the *villi*, in which the lacteals originate. There are no valvulæ conniventes in the large intestine, and but very few villi.

The different secretions of the alimentary canal are spoken of elsewhere.

Sect. 3. *Movements of the Alimentary Canal.*

The prehension of the food is usually entirely voluntary, but in the infant and some of the lower animals, it seems instinctive, as in the grasping of the nipple.

The object of *mastication* is to triturate the food

and mix it with saliva. The nature of the *teeth* varies in different animals. In the carnivora they all have sharp cutting edges, and move perpendicularly upon each other, so as simply to divide the food. In the herbivora the arrangement is favourable for great lateral movement of the lower jaw, and the molar teeth are very rough for the purposes of *grinding* the food. In man both objects are attained: the conformation of his mouth and teeth evidently showing that he was designed for a mixed sort of diet. A proper mastication of the food is of great importance to healthy digestion. Rapid eating is a frequent cause of dyspepsia, the stomach not being able so well to act upon imperfectly chewed food. When the food is thus properly comminuted, it is carried backwards to the fauces, and then into the pharynx by the act of *deglutition*. The tongue conveys it as far as the anterior palatine arches; these contract and close over the tongue so as to prevent the return of the bolus; and at the same time the posterior nares are closed by the junction of the posterior palatine arches with the uvula. The larynx is drawn forwards, and the epiglottis pressed down over the rima-glottidis, so as to prevent an entrance into it. In this way a sort of inclined plane is formed, down which the morsel slides, when it is seized by the constrictors of the pharynx, and so propelled down into the œsophagus. Deglutition is an *involuntary* act,—of a reflex character.

The propulsion of the food along the œsophagus, is effected by the peristaltic contraction of the muscular

coat of the latter, under the *direct contact* of the food. It is neither due to the will, nor to the reflex action of the spinal cord, since it occurs when all nervous communication is cut off. The contractions of the œsophagus take place in a rhythmical manner; but as the stomach becomes full, the intervals are longer.

In *vomiting*, the peristaltic actions of the œsophagus are reversed; and this reversion has been observed even after the separation of the stomach from the œsophagus, as a consequence of injecting tartar-emetic into the veins.

At the cardiac orifice of the stomach, where it is joined by the œsophagus, there is a sort of sphincter muscle, which is usually closed, but which opens by the pressure of the food upon it, and then closes so as to retain it. This closure is due to reflex action, for when its nerves are divided, the sphincter no longer closes, and the food regurgitates into the œsophagus. The opening of the cardia, is one of the first acts in vomiting.

The stomach of ruminant animals consists of four separate cavities, communicating with one another. The œsophagus does not terminate in the first of these, or the *paunch*, but continues onwards as a deep groove with two lips, which by closing, form a tube, which serves to convey the food into the *third* stomach. The food as first swallowed is but slightly masticated, and reaches the termination of the œsophagus in a dry bulky state. This separates the lips of the demi-canal, and passes into the first and se-

cond stomachs, where it becomes macerated in the fluids of these cavities. It is then regurgitated into the mouth by a reverse peristaltic movement of the œsophagus, in a regular succession of rounded masses. It is then thoroughly masticated and mixed with saliva, (the "chewing of the cud,") after which it is swallowed in a pulpy state; being now carried along the demi-canal, without opening the lips, into the *third* stomach, and thence into the *fourth*, where alone true digestion takes place.

SECT. 4. *Action of the Stomach—Chymification.*

The chief object of the stomach, is for the purpose of submitting the food to the solvent action of the *gastric juice.*

When the food has reached the stomach it is subjected to a peculiar peristaltic movement. This is produced by the contraction and relaxation of the various fasciculi of the muscular coat. This causes a complete revolution of the contents in every direction, and a consequent thorough trituration. Towards the end of the process, a sort of hour-glass contraction takes about four inches from the pylorus, by a shortening of the transverse fasciculi. The fluid portion is received into the smaller or pyloric end, while the solid portion is retained in the larger end until it is completely dissolved.

It is not certain how far these movements are under nervous influence. They are found to continue even after the section of the par vagum, although

the first effects of the operation are to suspend them. On the other hand, irritation of the par vagum has been found to produce these movements when the stomach was full, but not when empty.

The *Gastric Juice* is a secretion of the walls of the stomach; it is only found during the presence of food, or when the stomach is irritated by some solid body.

In the intervals between digestion, the mucous membrane is of a delicate pink colour, of a velvety appearance, and covered with mucus. Under the stimulus of aliment, it becomes turgid with blood, and numerous minute papillæ are seen, under the microscope, to erect themselves, so as to rise above the mucus covering the surface, from which a limpid, colourless, slightly viscid, and acid fluid distils, —this is the gastric juice. It is secreted, (through the agency of cell-growth,) by follicles of a tubular shape, which are closely packed together in bundles, their blind extremities resting upon the submucous tissue, and their open ends towards the cavity of the stomach. These follicles usually open into little depressions or pits, which may be seen over the membrane. The diameter of these pits is from 1-100th to 1-250th of an inch; from three to five gastric follicles open into one pit.

The *chemical composition* of the gastric juice is not definitely determined. That of man is known to contain free muriatic and acetic acids, to which its acid reaction is due. Blondlot's experiments go to show that the gastric juice of the dog contains nei-

ther of these acids, but that the acid reaction is due to the *superphosphate of lime.*

The gastric juice has the power of coagulating albumen to a great degree;—it is also highly antiseptic. Its peculiar properties are due to an organic principle named *Pepsin*, analogous to albumen in composition. This principle is soluble in cold water, but not in hot water. It combines with some of the acids, forming compounds which still redden litmus paper. It is chiefly remarkable for its great solvent power over albuminous substances. Artificial digestion may be caused, out of the stomach, by the action of a due admixture of dilute muriatic acid and pepsin upon various alimentary substances; the whole being kept at a temperature of 100° F. If the acid be used *without* the pepsin, no effect is produced at the above temperature; but at the boiling point solution takes place, presenting the same characters as when pepsin was used at the temperature of 100°. From this it appears that the acids are the real solvents; the pepsin being thought to serve as a *ferment*, producing some change in the substances on which it acts, disposing them to be dissolved by the acids, and replacing the effects of a high temperature, which would not be compatible with the safety of the stomach. Like other ferments, pepsin undergoes no change itself, and forms no combinations with the substances upon which it acts. Hence digestion may be considered as the result of the combined action of chemical solution and fermentation. It is a *vital* process, so far as

vitality is necessary for the secretion of the gastric juice.

The quantity of food which the gastric juice can dissolve within a given time, is limited. *Cold* retards the digestive process, hence the use of much cold water, or ice at meals, must be injurious.

The quantity of gastric juice secreted, is not so much regulated by the amount of food ingested, as by the wants of the system. Hence an excess of food, not being dissolved, will act as a source of irritation to the stomach. *Condiments*, as pepper, mustard, &c., act by gently stimulating the mucous membrane to increased secretion. If the irritation of the membrane be continued, it becomes red and dry,—the epithelium is abraded, irregular dark patches are seen, together with *aphthæ*. These changes are indicated by dryness of the mouth, furred tongue, accelerated pulse, and other evidences of fever. The Emotions sometimes produce similar effects. Those of a *depressing* nature occasion a pale flaccid condition of the membrane.

From experiments made upon different articles of food by gastric juice taken from the stomach, it appears that the flesh of wild animals is more digestible than that of the domesticated, probably from the less proportion of fat which it contains. Beef is more digestible than mutton, and mutton much more so than veal and pork; poultry is not so digestible as was supposed; cabbage in the raw state, has been found to be far more digestible than when boiled.

The food, when thus acted upon by the gastric juice, receives the name of *Chyme*. Its consistence varies with the relative quantities of solids and fluids ingested. Usually it is of a grayish colour, homogeneous, semi-fluid, and of a slightly acid taste. When the food has contained much oily matter, the chyme has the appearance of cream; when the diet has been farinaceous, it resembles gruel. The following is believed to be the condition in which the various alimentary principles exist in it: The protein compounds, whether animal or vegetable, are reduced to albumen, a part of which is dissolved, and a part held in suspension. Gelatin will be dissolved or not, according to its previous condition; if found in a tissue from which it cannot be easily extracted, it will pass on, nearly unchanged. Vegetable gum, if of the soluble form, is dissolved, as in the case of arabin, pectin and dextrin. Starch, when its vesicles have not been ruptured by heat, is sometimes broken down and dissolved, as by the ruminants, and the granivorous birds; sometimes it passes through the alimentary canal unchanged. Sugar is dissolved, when the stomach is in a healthy condition. Oily matters are reduced to the state of an *emulsion*. Many other substances, as lignin, resins, horny matter, &c., pass through unchanged, and are discharged among the feces, as entirely useless.

Sect. 5. *Action of the Intestinal Tube.*

The passage of the chyme through the pyloric orifice is at first slow, but it becomes more rapid as

digestion progresses. From this time it is propelled onwards by the simple peristaltic action of the muscular coat, which is excited by the immediate stimulus of the chyme, or of the secretions which are mingled with it. Its independence of nervous influence is seen from the fact that it will continue when all nervous communication is cut off, and from the difficulty of exciting contractions by stimulation of the nerves. The influence of the emotions upon this movement is probably exerted through the Sympathetic, which supplies the whole intestine.

In the duodenum, the chyme is mingled with the Bile and Pancreatic secretion. The effect of the *bile* is to separate the chyme into three portions:—a creamy pellicle on the top,—a whey-coloured fluid in the centre,—and an insoluble reddish sediment. The first two are destined for absorption; the latter is excrementitious.

The secretion of bile is of great importance, not only for the separation of certain matters from the blood, but also for the perfection of the digestive process. This is the obvious reason for the liver discharging so high up in the intestine. If the bile-duct be divided, so as to allow the bile to flow out by a fistulous opening, the animal will die of inanition. Again, if the duct be tied, constipation always occurs, in consequence of the want of stimulus to the peristaltic action. It is by stimulating the biliary secretion, that mercury acts as a *purgative*.

Although the liver is *constantly* secreting, the bile only flows into the duodenum when there is

chyme present. When not needed, it accumulates in the gall-bladder. Hence the gall-bladder is always found turgid in persons dying of starvation. The flow of bile into the intestine, is imputed to the pressure of the distended duodenum upon the gall-bladder; but it is probable that the peristaltic action of the muscular (middle) coat of the ductus choledicus may be excited, either through the sympathetic nerve, or by irritation at the orifice of the duct, as in the case of the salivary glands.

The influence of the secretion of the *Pancreas*, is not precisely determined.

After the food has passed the orifice of the ductus choledicus, the nutritious portion begins to be taken up by *absorption*, leaving the excrementitious matter, which is increased by the products of the secretion of the different intestinal glandulæ. The nature of these secretions is treated of in another place. The Cæcum in some animals is quite large; —occasionally there are two cæca. The secretion of the cæcum in herbivorous animals is acid during digestion, and their food is believed to undergo there a second digestion. This is not the case in man.

The act of *Defecation* is chiefly reflex, though partly voluntary. The retention of the feces is due to the contraction of the sphincter ani muscle. The action of this muscle is mostly *reflex*. Its power is lost, if the nerves be divided, or in injury to the lower part of the spine. If the mucous membrane be unduly excited, the muscles of defecation (dia-

phragm and abdominal muscles,) will, by reflex movement, be caused to act frequently—and overcome the contraction of the sphincter.

Sect. VI. *Of Hunger and Thirst.*

The sensations of Hunger and Thirst are instinctive, being intended as guides in the reception of food and drink.

The sense of hunger is usually referred to the stomach. It is not caused by mere emptiness of that organ, since if the previous meal has been sufficient, no hunger is produced, though the stomach be empty. It is not due to the action of the gastric juice upon its coats, as has been supposed, since this fluid is only secreted under the stimulus of food; neither is it owing to the distention of the gastric follicles.

The probability is, that the *general want of the system* is the remote cause, acting through the medium of the sympathetic nerve. Under this influence, there is a determination of blood to the stomach which may be the *proximate* cause of hunger, by acting upon the par vagum nerve. When food is taken into the stomach, the secretion is excited, and the capillaries unloaded. The sensation is removed by introducing nutriment into the system in *any* mode. It is also abated by the section of the par vagum. A certain degree of *bulk* seems necessary to excite the proper amount of secretion. The sense of hunger is much influenced by the

mental emotions. It may also exist without the mind taking cognizance of it, on account of its being pre-occupied,—as is seen in hard students.

The sense of Thirst indicates the general deficiency of fluids in the system. The *immediate* seat of the feeling is the fauces. It is relieved by introducing fluid into the system by *any* mode, as by the rectum, skin, &c. In the same way, it may be excited by diarrhœa, perspiration, or any other excessive loss of fluid; also by certain kinds of spicy food.

The feeling of Satiety is not produced by the mere fulness of the stomach, but by the *general* feeling of the system, from the absorption of nutriment.

CHAPTER VI.

ABSORPTION.

SECT. 1. *Absorption from the Digestive Cavity.*

The food having been duly prepared by the digestive process, and reduced to chyme, is ready for the nourishment of the system, when it has been absorbed.

In the Invertebrata, this absorption takes place directly from the digestive canal into the veins. In the vertebrata, there is a distinct set of vessels appropriated to the function—the *Lacteals.* These are found copiously spread upon the small intestine, below the orifice of the ductus choledicus; sparsely

over the large intestine; and not at all in the stomach. Still, substances may be absorbed directly from the stomach into the blood-vessels, by *endosmose.* This is the case with saline substances and nutritive matters in a state of perfect solution,—as gum, sugar, pectin, soluble albumen, and gelatin,—as has been proved by the experiment of tying up the stomach at the pylorus, and injecting these substances into its cavity. The essential conditions for the *endosmotic* movement are, two liquids of different diversities separated by a thin membrane; the movement being always *towards* the fluid of greatest density. These conditions are found in the stomach, which is abundantly supplied with blood-vessels. The blood being a denser fluid, there will be a tendency of the saline, and other soluble matters, to flow *towards* it. The veins are principally concerned in this act of absorption, the reason of which is that their walls are thinner than those of the arteries: they are also distributed nearer the surface, and the direction of the current of blood in them is more favourable to absorption, since the resistance is constantly diminishing, as may be proved on physical principles.

This mode of absorption by veins, occurs also, to some extent, in the intestine; hence a reason for its great vascularity. But there is no doubt that the true nutritive absorption is chiefly performed by the Lacteals, which are so called from the milky character of their contents. These take their origin in the *villi* which are so abundant in the small intes-

tine,—each villus containing a simple lacteal which arises by several smaller branches, none of which have open mouths. The branches appear often to draw towards each other, forming loops. These loops are imbedded in a mass of *cells* at the extremity of the villus, which are the true agents of the selection of the nutritive materials from the chyme: so that it is by a process of *cell-growth* that lacteal absorption is really effected,—the cells filling up, bursting or deliquescing, and discharging their contents into the lacteals. This *selective* power of the cells is purely a vital property;—it is analogous to that possessed by the cells of vegetables, which select from the pabulum common to all of them the materials requisite for their own peculiar products.

The experiments of Tiedeman and Gmelin prove that the lacteals take up, almost exclusively, *nutritious* matters; while the veins absorb the odorous matters, and saline substances: the colouring matters do not appear to be absorbed to any extent, but pass out of the system unchanged.

Sect. 2. *Of the Chyle and Lymph.*

The milky fluid formed in the lacteals is called the *Chyle*. In its passage through these vessels, it undergoes considerable alteration, as will be directly explained.

The lacteals, commencing on the surface of the intestines, then running together on its walls, to form larger trunks, which converge and unite with

each other on the mesentery; they then pass onwards through the mesenteric glands. These do not correspond in structure with the proper glands, being simply composed of a convolution of lacteal trunks, somewhat dilated, and freely supplied with blood-vessels, which, however, do not communicate with the interior of the lacteals.

The chyle drawn from the lacteals, before they enter the mesenteric glands, contains albumen completely dissolved, also the salts in a state of solution, but no fibrin, since it does not coagulate spontaneously. It also contains the oily matter in a state of suspension, in the form of minute globules. These *oil-globules* are more abundant in the chyle of man and the carnivora, than in the herbivora. The milky colour of the chyle has been supposed to be due to these oil globules; but Mr. Gulliver has ascertained that it is really owing to the presence of a great number of far more minute particles, called the *molecular base.* These molecules seem to be spherical, of a diameter of 1-36,000th, to 1-24,000th of an inch. They abound most in rich, opaque chyle, and are remarkable for their unchangeableness under the action of chemical reagents which affect the proper chyle corpuscles. Ether completely dissolves the molecular base, whence the inference that it is composed of *oily* materials.

The milky appearance sometimes exhibited by the serum of the blood, when drawn shortly after a full meal, is probably due to the molecular base, and not to the absorption of milk.

The first change which the chyle undergoes in its passage towards the blood, is observed just before the lacteals enter the mesenteric glands. It consists in the appearance of fibrin, and the diminution of the oil-globules. The fibrin is formed at the expense of the albumen, which subsequently diminishes in proportion as the fibrin increases. The proper *chyle-corpuscles* now begin to appear, and are constantly found throughout its subsequent course. They are particularly abundant in chyle drawn from a mesenteric gland.

The chyle-corpuscles originate in the mesenteric glands. They are supposed, by Carpenter, to be the altered epithelium cells which line the lacteals in their passage through these bodies. The epithelium of the lacteal before it enters the gland, is thin and scale-like: *within* the gland, it is composed of numerous layers of spherical nucleated cells, of which the superficial ones are easily detached, and appear to be identical with the chyle-corpuscles. They vary very much in size, from a diameter of 1-700th, to 1-2600th of an inch. This variation in size depends, probably, upon the period of their growth. They are granulated on their surface; but the nuclei cannot, very readily, be defined. There is a strong resemblance between them and the colourless corpuscles of the blood,—especially in the thoracic duct.

The *function* of the chyle-corpuscles may be inferred to be, to convert the albumen of the chyle into fibrin; for the chyle is found to coagulate spontaneously, *only* when these corpuscles are pre-

sent, and the amount of fibrin observed is in proportion to the diminished quantity of albumen. After leaving the mesenteric gland, the lacteals converge towards the *Receptaculum Chyli*, into which, also, the lymphatics discharge. From the receptaculum arises the *Thoracic duct*, which passes upwards in front of the spine, to terminate at the junction of the left subclavian and jugular veins. A smaller duct receives some of the lymphatics of the right side, and there terminates at a corresponding part of the venous system; but none of the lacteals discharge into it.

The chyle taken from the receptaculum and thoracic duct, coagulates like blood,—the *clot* comprising most of the chyle-corpuscles; the *serum* closely resembling the serum of the blood. Sometimes the separation into serum and clot is not so distinct, the coagulum appearing like a jelly.

The *Lymphatic* system much resembles the lacteal. The Lymphatics are distributed throughout the whole body, chiefly in the skin. They commence neither by closed nor open extremities, but from a network, from which the trunks arise. In their course, they pass through glands termed *lymphatic glands*, strongly resembling the mesenteric; and finally terminate in the same general reservoir—the *receptaculum chyli*.

The Lymphatic system is in its most developed state in Mammalia, the vessels having firmer walls, and more numerous valves than in the lower classes. The glands are also more numerous in them.

The chief differences between Lymph and Chyle, are the following:—Lymph is perfectly transparent and colourless; Chyle is opaque and milky;—Lymph contains much less solid matter, and is nearly destitute of oily materials. The following table shows the distinction between Chyle and Lymph:—

	Chyle.	*Lymph.*
Water, ...	90.237	96.536
Albuminous matter, .	3.516	1.200
Fibrinous matter, . .	0.370	0.120
Animal extractive matter,	1.565	1.559
Fatty matter, . . .	3.601	a trace.
Salts, ...	0.711	0.585
	100.00	100.00

From this analysis, it appears that the chief chemical difference between the Chyle and Lymph is the greater proportion of assimilable substances—albumen, fibrin and fatty matter—contained in the former.

Function of the Lymphatics.—It was formerly supposed that the lymphatics took up, and carried out of the system, all the effete matter which resulted from the constant waste and disintegration of the organs. This doctrine, however, is not tenable; for it seems absurd to imagine that this *effete* matter would be mixed up with the newly-ingested aliment, and so thrown into the blood, instead of being immediately carried out;—and the actual composition of the lymph also is opposed to it, since it contains highly *nutritious* substances. The *true* function

of the lymphatic, or absorbent, system then is *that of nutrition;*—it takes materials which are capable of being used for the nutriment of the system, whether these be furnished by the external world, or by the disintegration of the system itself. It is true, that other substances are, at times, found in the lymphatics—as, for instance, *bile*, when some obstruction exists in the gall ducts. So also the lymphatics, in the neighbourhood of a large abscess, have been found to contain *pus;* and when the limb of an animal, around the upper part of which a bandage is tied, is immersed for some hours in tepid milk, the lymphatics of the skin are found to contain that fluid; also, when saline substances are applied to the skin, they are usually more readily detected in the lymphatics than in the veins. But these facts only prove, that the walls of the lymphatics are permeable by substances in a state of solution. The more ready absorption of such substances by the lymphatics, than by the veins of the skin, may be accounted for from the fact of the very free distribution of the lymphatics upon the skin, and the greater tenuity of their walls. In the lungs, the case is different,—matters, when injected into the pulmonary tissue, finding their way much more readily into the blood-vessels, on account of their more abundant existence. As regards the absorption of pus from an abscess or ulcer, the probability is that the absorbents must themselves have been laid open in the process of ulceration, since the pus-globule is too large to have gained admittance in any other way.

Hence, it appears that the lymphatics, as well as the lacteals, convey *nutritive* materials, although derived from a different source. If this view be correct, we must look to the veins as the true absorbents of the *effete* matters of the body.

The fluid of the Thoracic Duct, as we have seen, is made up by the admixture of the chyle and lymph. It contains the chyle-corpuscles and fibrin, in the maximum quantity, the oily matter in minimum quantity; and the albumen in medium quantity. It resembles the blood in every respect, except that it contains less fibrin and none of the red corpuscles, though the latter sometimes find their way into it, so as to communicate a perceptible reddish tinge. It is the belief, however, that this is the result of accident,—the operation for exposing the thoracic duct, having laid open some of the lacteals or lymphatics, which took up blood by their open mouths, and then transmitted it to the duct. Mr. Gulliver and others suppose, on the contrary, that the red corpuscles are really in the process of formation in the thoracic duct, and that they are formed from the chyle-corpuscles, which are identical with the white corpuscles of the blood. Carpenter adopts the former view.

In noticing the changes which the Chyle undergoes on its passage from the lacteals to the thoracic duct, nearly all the oil globules are seen to disappear, whilst the fibrin has very much increased. The fibrin cannot be formed directly from fat, but from *albumen*, hence we must suppose that a con-

version of fat into albumen takes place, by the introduction of nitrogen in the lacteals. This nitrogen can only, so far as we know, be derived from the blood which supplies the lacteals. In confirmation of this view, it may be remembered, that the secretion of the liver, which is supplied chiefly by the blood of the mesenteric veins, consists almost entirely of *non-azotized* matters.

The movement of the chyle and lymph along the absorbents, is believed to be due to a sort of peristaltic action of the fibrous or middle coat of these vessels. This fibrous structure is particularly evident in the thoracic duct. The retrograde movement is prevented by the *valves* with which the absorbents are supplied. The general movements of the body may also assist in propelling the chyle and lymph onwards.

SECT. 3. *Absorption from the Skin and Pulmonary surface.*

The mucous membrane of the alimentary canal is not the only channel through which matters may be absorbed into the system. The skin, and the pulmonary mucous membrane are also capable of absorbing both liquids and vapours. In some of the lowest animals, and in the early condition of the highest, the external surface is as important a channel for absorption, as the mucous membrane of the digestive canal.

A proof of the ability of the skin to absorb, is given in the fact, that intense thirst may be allevi-

ated by immersing the body in water, or applying wet clothes to the body; also, in life being prolonged in persons unable to swallow, by the immersion of the body in a bath of milk and water. So again, it has been found, that after bathing in infusions of madder, rhubarb, and turpentine, the urine was tinged with these substances; a garlic plaster affected the breath, although care was taken that the odour should not be received into the lungs; gallic acid has been found in the urine after the external application of oak bark. In this way, also, we apply some of our medicines—as the mercurial ointment, &c.

Absorption through the skin is chiefly accomplished by means of the *lymphatics*, because they are much more numerous near the surface than the veins, and their walls are thinner. In the same way, various matters may be introduced through the lungs; thus, if we breathe an atmosphere, through which the vapour of turpentine is diffused, it soon produces the characteristic odour of violets in the urine. By the same means, we produce an impression upon the system, through the inhalation of vapours; and it is probable that the various miasmata are thus introduced into the system.

The facility of absorption from the skin and lungs appears to be inversely proportionate to the quantity of fluid in the circulating vessels.

CHAPTER VII.

OF THE BLOOD.

SECT. 1. *Composition and Properties of the Blood.*

The Blood, while circulating in its vessels, presents a perfectly homogeneous appearance, of a somewhat oily aspect, and having an average specific gravity of 1050. When drawn from the body and left to itself, its elements undergo a new arrangement, called its *coagulation;* by which process it separates into two distinct portions; the solid portion called the *cruor*, *crassamentum* or *clot*, and the liquid portion, termed the *serum*. The clot consists of the fibrin, which, in the process of coagulation entangles the red corpuscles in its meshes, and it becomes dense in proportion to the amount of fibrin it contains. The serum consists of the albumen and saline matter dissolved in water. There is usually some serum remaining in the clot, from which it may be removed by pressure. The difference between the composition of the blood when circulating, and in the coagulated state, may be thus stated :—

When circulating.

Fibrin,....... Albumen,.... Salts.........	In solution, forming Liquor Sanguinis.
Red corpuscles,—	Suspended in Liquor Sanguinis.

When coagulated.

Fibrin,....... Red corpuscles.	Crassamentum or Clot.
Albumen,.... Salts.........	In solution, forming Serum.

The coagulation of the blood is entirely due to the fibrin;—the red corpuscles are passive, as may be shown in various ways: by filtering the freshly drawn blood of a frog, the liquor sanguinis passes through perfectly clear, and subsequently coagulates, leaving the corpuscles on the filter; by constantly whipping freshly drawn blood with a bundle of twigs, the fibrin will adhere to them in long shreds, while the red corpuscles will remain suspended in the serum without any tendency to coagulate.

The coagulation of the blood is no proof of its death, as was thought by Hunter; on the contrary, it is an evidence of vitality, since, as has been shown, the very first act of its organization is coagulation; when separated from a living surface, however, the coagulation of the blood may be regarded as the last act of life, since it afterwards passes into a state of decomposition.

The length of time which elapses before coagulation, after the blood has been drawn, varies very much. As a general rule, the more elaborated and concentrated the fibrin is, the more slowly will it coagulate, and the firmer will be the clot. Thus, when a quantity of blood is drawn at one bleeding, into several vessels, that which is received into the first will coagulate most slowly, but form the firmest clot; while that drawn last will coagulate more rapidly, but the clot will be thinner. The coagulation is accelerated by heat, and retarded by cold; but it is not prevented by extreme cold; since if blood be frozen as soon as drawn, it will coagulate

on being thawed. Again, the coagulation is accelerated by exposure to the air; and it is retarded, though not prevented, by complete exclusion from it. Constant agitation will delay the coagulation; but that mere *rest* is not the cause of it, is proved by the experiment of including a portion of blood between two ligatures in a living vessel; it will remain fluid for some time. Various chemical agents also retard this process, especially solutions of the neutral salts; but they do not prevent it: they seem, however, to produce some mechanical change upon the fibrin, hence the clot is not so firm after their use.

Carbonic acid is usually extricated during coagulation.

The coagulating power of the fibrin is sometimes destroyed, so that the blood when drawn will not separate into serum and clot. This may result from poisonous matter introduced from without, which acts as a ferment—as seen in malignant typhus fever, in glanders, &c.; or from some morbid condition originating in the system, depending upon a deficient nutrition or excretion, as seen in scurvy, purpura, asphyxia, and in animals over-driven; and also from violent shocks or impressions upon the nervous system, as electricity, lightning, concussions of the brain, coup-de-soleil, &c. Sometimes there is a remarkable *retardation* in the coagulation of the blood,—its fluidity continuing for some days, but ultimately coagulating.

The relative proportions of serum and clot vary.

When the coagulation is rapid the clot retains a large portion of serum, increasing its apparent bulk. It is said that coagulation occurs more rapidly in metallic vessels than in those of glass or earthenware, and that the proportional amount of clot is much increased.

Analysis of the Blood.

The following is the proximate analysis of the blood, according to Simon.

Water.	
Protein compounds,	Fibrin. Albumen. Globulin.
Colouring matters,	Hæmatin. Hæmaphæin.
Extractive matters.	Alcohol-extract. Water-extract. Spirit-extract.
Fats,...........	Cholesterin. Serolin. Red and white solid fats containing phosphorus. Margaric acid. Oleic acid.
Salts,...........	Albuminate of soda. Phosphate of lime, magnesia, and soda. Sulphate of potassa. Carbonates of lime, magnesia and soda. Chlorides of sodium and potassium. Lactate of soda. Oleate and margarate of soda.
Iron,—Condition doubtful.	
Gases,..........	Oxygen. Nitrogen. Carbonic acid.
Sulphur.	
Phosphorus.	

Traces of the following substances are occasionally found in disease:—Sugar, urea, bilin and its acids, biliphæin or yellow colouring matter of bile, certain salts, copper, manganese and silica. As many as forty-two principles have been discovered in the blood at different times; Lecanu has reduced the number to twenty-seven.

The following may be taken as the average amount of the more important constituents of the blood in health, although they are subject to considerable variation:—There is a greater amount of solid matter in the blood of the male than in the female, except in the case of albumen; in 1000 parts of blood, the quantity of albumen amounts to about 70, with very little variation. The Corpuscles vary considerably, rising in the male as high as 116, sinking to 110.5; average—140; in the female, they may rise to 167, and sink to 71.4; average—112. The greater variation in the case of the female may be due to the catamenial discharge, which diminishes the quantity of corpuscles. The average amount of Fibrin in the male, is 2.2; it may rise to 3.5, or 4, but does not sink below 2. In the female, the average is about 2; it may rise to 3, and fall to 1.8. The Fatty matter varies from 3.5 to 4.5; the variation is probably due to the amount contained in the food. The Saline constituents, obtained by drying and incinerating the whole mass, usually amount to between 6 and 7 parts in 1000; more than one-half of which are composed of the chlorides of sodium and potassium,—the remainder is made up of the tribasic

phosphate of soda, the phosphate of lime and magnesia, sulphate of soda, and some phosphate and oxide of iron. Most of these salts are held in solution by the serum. The iron is contained chiefly, if not entirely, in the red globules. The alkaline reaction of the serum is thought to be due to the tribasic phosphate of soda. The quantity of water is estimated at about 780 to 785 parts. There are also some extractive matters, and some "ill-defined" animal principles.

We will now consider some of these constituents separately. *Red Corpuscles.*—These exist very sparingly in the blood of the Invertebrata, which is consequently of a *white* colour. Their proportion in the blood of the vertebrata also varies,—seeming to be connected with the relative activity of the respiratory function in each case. Their form is that of a flattened disk, which is circular in man and most of the mammalia, but oval in birds, reptiles and fishes, and a few mammals. These disks are flattened cells, whose walls are transparent, but whose contents are coloured. This can easily be shown, by floating them in water, when this fluid will be absorbed into the cells by *endosmose*, and cause them to swell out, and finally to rupture. If they be put into a thick solution of gum or sugar, the movement will be from within outwards, so as to cause the disks to have a shrunken appearance. Hence, in examining the blood-disks, they should be floated in a fluid of about the same density as serum.

As respects the existence of a *nucleus* in the Red

Corpuscles, it is the present belief, that in those of mammalia there is no distinct nucleus,—the dark spot which is seen in their centre being merely the effect of refraction in consequence of the double-concave form of the disk: when the corpuscles are treated with water, by which their form is altered, this dark spot disappears. Some physiologists contend for the existence of a nucleus in the mammalian corpuscles, although they cannot be seen, on account of their high refractive power. The nucleus, however, is distinctly visible in all the other vertebrata, as may easily be made evident by treating the corpuscles with water, when the contents will escape from the rupture of the cell-wall, and the colouring matter can be distinguished from the nuclei. The nucleus consists of an aggregation of minute particles, which are doubtless the *germs* of future cells.

The size of the red corpuscles varies very much, not only in different animals, but even in the same animal. Thus, in man, it varies from the 1-4000th to the 1-2800th of an inch; the average being about the 1-3400th. This is also about the average size of the mammalian corpuscles in general, with the exception of the Musk-Deer, in which they are less than the 1-12,000th of an inch in diameter. The Camel tribe, alone, of mammals, has the blood-disks of an oval shape; their long diameter being about the size of that of man; the short diameter only about one half of this. In Birds, the diameters are to each other, about as 1 to $1\frac{1}{2}$ or 2. The size of the disks

usually corresponds with the size of the bird: thus, in the ostrich, the long diameter is about 1-1650th of an inch and the short diameter 1-3000th; while, in the sparrow, &c., the long diameter is about 1-2400th, and the short not more than one half of this.

The corpuscles are largest in reptiles. Those of the frog are peculiarly suited for study, their long diameter is about the 1-1000th of an inch, and their short diameter about the 1-1800th. The Proteus, Siren and such species, are remarkable for the large size of their blood disks; thus the long diameter of the corpuscles of the Proteus is about the 1-337th of an inch. In those of the Siren, it is about 1-435th of an inch. The long diameter of the nuclei of these disks is about the 1-1000th of an inch, which is more than three times the length of the entire human corpuscle. The variation in the size of the corpuscles in the same animal is easily understood, when we consider them to be cells, at different stages of growth.

The form of these corpuscles is often observed to change during their circulation, owing to the pressure; thus, in the narrow capillaries, they may be observed to become elongated, twisted or bent, to facilitate their passage.

The chemical composition of the walls and nuclei of the red corpuscles is very different from that of their contents. The former are composed of *globulin,* which is a protein-compound; the latter consist of a proximate principle termed *Hæmatin;*

and it is to this, that the red colour of the blood is due. Its formula is $C^{44}\ H^{22}\ N^{3}\ O^{6}+Fe$. The iron forms an essential constituent of it. When completely separated from albuminous matter, hæmatin is a dark brown substance, insoluble in water, alcohol, and ether; but soluble in these, if they contain acids or alkalies. When burned, it yields a notable quantity of the peroxide of iron. But the iron is not the *cause* of the colour, as was proved by Scherer, who completely dissolved it out by aid of acids, and yet the animal matter left, when boiled in alcohol, produced a deep red colour. Liebig's opinion that the iron existed in the blood in the state of protoxide or peroxide, would seem refuted by the fact that weak acids have no effect in removing it from the hæmatin—which they would have, upon either of these oxides. It is not certain in what state the iron does exist. It is quite probable that the production of hæmatin is the result of chemical action taking place in the cells or corpuscles, since nothing like it exists in the serum in which they float. The fluid portion of the chyle holds a large quantity of iron in solution, which seems to be drawn into the red corpuscles, and united with the other elements of the hæmatin, as soon as ever it is carried into the circulation.

The precise chemical difference between the hæmatin, as it exists in arterial and in venous blood, is not known. The florid colour of arterial blood is changed into the purple hue of the venous blood, in circulating through the capillaries of the system;

and a converse change is undergone in the passage through the capillaries of the lungs. In the first case, the blood gives out oxygen and becomes charged with carbonic acid; in the second, it gives off carbonic acid, and acquires oxygen. A similar change in colour may take place out of the body, under similar conditions: thus venous blood, when exposed to the air, and particularly if exposed to oxygen, acquires a florid hue; while arterial blood, when in contact with carbonic acid, becomes as dark as venous blood. The mere removal of the carbonic acid is not sufficient to restore the arterial colour, since this can be accomplished by hydrogen; it requires the presence of oxygen, or the addition of saline matter to the blood. According to Scherer, there is good reason for believing that the change of colour in the blood is due entirely to *physical* causes, as will be explained under the head of Respiration.

As regards the *origin* of the red corpuscles, it may be considered as pretty well established, that, like other simple isolated cells, they are constantly being reproduced, and as constantly dying out. Bleeding rapidly diminishes them; the same effect is produced by chlorosis; on the contrary, they are rapidly regenerated under the use of iron, and in plethora. There is no good reason for supposing that the colourless corpuscles serve as nuclei for future red corpuscles, as maintained by Wagner, Gulliver and others, since while the diameter of the former is very constant, that of the latter varies extremely. Their original formation has been clearly

traced to the minute granules, (probably cell-germs,) in the cells of the germinal membrane. These become blood-corpuscles, and their subsequent increase and reproduction can only occur like the increase of any other cells, by the evolution of successive generations of germs from the parent. This multiplication may arise, either from a division of the cell into six smaller ones, which afterwards attain their full size; or from the corpuscles assuming a sort of hour-glass form, by contracting across the middle, and by an increase of this contraction, causing a division of them into two.

As regards the *function* of the red corpuscles, various theories are held: Hunter considered them the least important part of the blood; Magendie supposed their only use was to demonstrate the circulation. Wagner, Henle, Schultz and others, believe that they elaborate the fibrin of the blood out of the albumen; but as they do not exist in the invertebrata, they cannot be essential in the plastic or formative functions. Again, their number increases in those animals whose respiratory process is active,—hence they are believed to be carriers of oxygen to the various tissues, and of carbonic acid from these tissues to the lungs. Liebig supposes the *iron* to be the real agent in the respiratory process,—becoming changed from a protoxide to a peroxide, by receiving oxygen from the lungs; and again becoming a protocarbonate in the systemic capillaries by giving up its additional oxygen, and receiving carbonic acid in return. This, however, is specula-

tion, as there is no proof of the iron being in the state of *protoxide*. It is quite certain that the animal functions are greatly dependent upon the red corpuscles for their activity. Simon supposes them to carry the oxygen, not for the general purposes of the economy, but for their own particular use,—to convert the globulin into the urea, bilin and choleic acid of the blood, and the hæmatin into hæmaphæin. It is certain that the large amount of oxygen carried into the system is not needed for the conversion of albumen into fibrin, since these, as we have seen, are so nearly identical.

Besides the red corpuscles of the blood, there are others called *colourless* or *white corpuscles*, which seem identical with those of the chyle and lymph. They differ in their appearances from the red corpuscles: thus, while the size of the latter varies very much in different animals, that of the white corpuscles has a great degree of uniformity, being in all cases, very near 1-3000th of an inch in diameter. Hence it would seem unlikely that the one could ever be converted into the other. Again, their appearance under the microscope is different; the colourless corpuscles are filled with minute granules, which are seen to be in active movement. By the action of a dilute solution of potash, these cells rupture, discharging their molecules, which are doubtless germs of new cells. Moreover, when the corpuscles rupture spontaneously, the fluid which they set free shows a tendency to assume a fibrous arrangement.

The distinction between the two may also be perceived in the capillaries of the frog's foot, in which the colourless corpuscles are seen to remain close to the sides of the vessel, where the movement is slow, while the red corpuscles move rapidly through the centre of the current. Often the colourless corpuscles evince a tendency to adhere to the side of the vessel.

Function of the white corpuscles. Dr. Carpenter's idea that the office of these cells is to elaborate fibrin out of the albumen of the blood, is sustained by the following considerations:—They are found in *all* animals possessing a circulation,—the red corpuscles are only found in the vertebrata. They are found wherever the production of fibrin is going on, and their number bears a close relation to the *amount* of fibrin; thus in inflammation, where the fibrin is so much increased, the number of white corpuscles is proportionally augmented. They are also seen in great quantities in the vessels of inflamed parts, and likewise in the exudations from the blood upon wounded or inflamed surfaces. So again, in the embryonic condition of animals, when the *formative* process is particularly active, especially in the early stage of fœtal life, the white corpuscles are very abundant. We may consider the white corpuscles, then, as isolated floating cells of a transitional character, whose function is to work up the organizable material, albumen, as it is thrown into the circulation, into fibrin, for the supply that is constantly demanded by the nutritive processes.

This they effect by a simple process of cell-growth; generation succeeding generation, just like the vegetable-cells of plants, or the transient generations of cells in the egg, whose office is to elaborate the proper material for the future nutriment of the organized structure.

The Fibrin of the blood is the highly organized material from which the various tissues and organs are nourished. It exists in the *fluid* state, and is withdrawn for the purposes of nutrition almost as fast as it is formed: the demand being supplied partly, as just shown, by the elaboration of the white corpuscles, and partly by the chyle and lymph. A proper amount of fibrin is requisite in the blood to enable it to circulate in the vessels. If defibrinized blood be injected into the vessels of an animal, typhoid symptoms are produced.

The Albumen is the raw material out of which, not only the fibrin, but many other substances are generated: thus the albuminous compounds of the secretions, the horny matter of the skin, hair, nails, &c., the gelatinous tissues, the walls of the red corpuscles, and others are transformations of albumen. The constant supply which is needed, is afforded by the food, which, as has been shown, must be converted into albumen, by the process of digestion.

The use of the Saline matter is chiefly to supply the mineral materials requisite for the composition of certain tissues and secretions, as bone, teeth, urine, sweat, &c. There seems to be an instinctive desire among all animals for salt; it is not merely useful as

a condiment, but it is essential to the healthy condition of the animal.

The Fatty matter is derived from the food; its chief use is for the maintenance of animal temperature by the combustive process. What is superfluous of it may either be deposited as fat, or eliminated by the liver, the sebaceous follicles, or the mammary gland in females. The blood also appears to contain a fat peculiar to nerve matter, containing nitrogen and phosphorus, but it is uncertain how it is generated.

The Water of the blood exists in large quantities, its presence being all-important for the proper fluidity of the blood. The quantity of water is very nearly fixed, in a state of health; any excess constantly passing off by the different secretions; and it is as constantly renewed from the fluids received into the stomach, or by absorption through the skin and lungs. A deficiency of water occasions *thirst.*

SECT. 2. *Pathological Changes in the Blood.*

The normal proportions of the constituents of the blood are liable to great variation in disease,—and this may be either the cause or the effect of the disease. For example, some local injury produces an inflammation of a part; the relation of the part to the blood which passes through it is altered; in consequence of this, the blood itself is changed in its properties, and so becomes the source of disturbance to other remote parts of the system.

On the other hand, Fever may be taken as an example, of a contamination of the blood proving the cause of general disease—the blood being originally affected by the introduction into it, of some morbific matter.

The following is Simon's table of the modifications of the blood in disease:—

1. *Hyperinosis*, (an excess of fibre,) including inflammations, erysipelas, phthisis, medullary carcinoma, and others.
2. *Hypinosis*, (a diminution of fibre,) including all the fevers, especially typhus, and the cruptive diseases, together with cerebral hemorrhage.
3. *Spanæmia*, (poverty of the blood,) including anæmia and hydræmia, carcinoma, scrofulosis, scorbutus, hemorrhages, and plague.
4. *Heterochymeusis*, (foreign mixtures,) including cholera, morbus Brightii, diabetes, icterus, &c.

In Inflammation the quantity of fibrin is vastly increased, mounting up as high as seven, eight or even ten and a half parts in a thousand, according to the intensity of the case. There is also constantly observed an increase of the tritoxide of protein in the blood, and a great disposition of the red corpuscles to arrange themselves in rows. The white corpuscles are also increased in number, and they separate from the red, adhering rather to the fibrin. These phenomena may be witnessed in a single drop of inflammatory blood under the microscope. The increased amount of fibrin is an invariable accompaniment of inflammation, whether or not it be complicated with other disorders.

In Fevers there is a great diminution of fibrin, and rather a tendency to an increase of the red cor-

puscles. The loss of fibrin is particularly seen in typhoid fevers, being reduced sometimes as low as 0.9; but if any inflammation should be developed in the course of the fever, immediately the proportion of fibrin rises. An excess of fibrin is not much lessened by copious bleeding, even if this be repeated; but certain medicines appear to exert an influence upon it, particularly mercury. A deficiency of fibrin produces a tendency to congestion and hemorrhage; hence the liability to these disorders, in the course of fevers.

An unusual amount of red corpuscles produces the state of system called *plethora* or fulness. In such cases there is a tendency to local congestions, and to hemorrhages. Hence we can understand the value of blood-letting in such cases;—it acts by rapidly diminishing the quantity of red corpuscles. Plethoric persons are not more exposed than others, to inflammation. In apoplexy, the blood exhibits a diminution of fibrin.

The opposite state of system to plethora is *anæmia,*—in which there is a great diminution of red corpuscles. This is often caused by repeated hemorrhage. Chlorosis exhibits the same diminution of red corpuscles,—in extreme cases they sink as low as 27, (standard, 127.) The influence of a generous diet, and particularly of the administration of iron, in reproducing these corpuscles, is very evident. The blood in anæmia and chlorosis exhibits the *buffy coat;* since this depends, as will be shown presently, upon the greater *relative* amount of fibrin to red globules.

In Scrofula there appears to be a diminution both of red corpuscles and fibrin.

The same condition of the blood was found, by Andral, in the various Cachexiæ.

The amount of albumen in the serum is diminished in Albuminaria, or Bright's disease of the kidney, in which an excess of it is found in the urine. According to Andral, the amount of albumen present in the urine is exactly proportionate to the diminution of it in the serum.

The proportion of the saline matters is not so liable to be altered by disease.

The blood may also be affected by the presence of other matters, either such as have been introduced from without, as medicinal agents, or a specific virus acting as a *ferment;*—or such as are produced within, and which ought to have been removed by the process of excretion, such as carbonic acid, urea, uric acid, the biliary and other matters. Some of the specific matters introduced into the blood from without, appear to poison it, destroying its vitality, and causing general decomposition of the solids and fluids, even before death takes place. Such is the case in malignant fevers, in glanders, in the bites of venomous serpents, &c.

The *buffy coat* is the appearance which the blood assumes when drawn, in cases where the amount of fibrin is relatively increased over the red corpuscles. Thus, in inflammation, the fibrin is *actually* very much increased, causing a delay in its coagulation. This allows the corpuscles time to sink to

the bottom, leaving the upper part of the clot composed only of fibrin, which is consequently nearly destitute of colour, and very tenacious in its character; while the lower part of the clot is of a very deep colour, and very variable. In these cases, the upper stratum, or buffy coat, being composed of highly elaborated fibrin, undergoes a slow contraction after coagulation, which draws in the upper edges of the clot, and produces the *cupped* appearance. The buffy coat is also seen in cases where there is no increase of fibrin, but where there is simply a diminution of the red corpuscles. Thus in chlorosis, the buffy coat is as evident as in inflammation; but the size of the coagulum is much less, on account of the diminished amount of solid matters.

CHAPTER VIII.

OF THE CIRCULATION OF THE BLOOD.

The object of the Circulation of the Blood is to convey to every part of the organism the materials for its growth and renovation; and also to carry out of the system the particles set free by the waste of the system. Hence the Circulation is subservient to the processes of Nutrition and Secretion. Another very important purpose of the circulation is to convey that due supply of oxygen to the nervous and muscular tissues which is essential to their action; and also to carry off the carbonic acid, which would speedily prove fatal, if retained. Hence we

find that the energy of the respiration bears a relation to the rate of the circulation.

Sect. 1. *Varieties of the Circulating Apparatus in Animals.*

The condition of the circulation, and the form of the circulating apparatus, are very different in different animals. In the lowest order of animals and in the embryonic condition of the higher, there are no distinct vessels, but each part, or each individual cell, has the power of directly absorbing the nutritious matter either from without, or from their digestive cavity.

Vessels are first met with in the entozoa and in the acalephæ or jelly-fish. These vessels take up the nutritive fluid from the digestive cavity, upon the walls of which they spread out, like the roots of plants in the soil. They then unite in trunks conveying the nutriment to every part; these trunks afterwards subdivide into smaller or capillary branches, some of which going to the surface, are subservient to aeration. The fluid is thên collected by other trunks, which carry it back to the point from which it started. The movement here is analogous to that of the elaborated sap in vegetables, being due to the varying affinities existing between the nutritive fluid, and the parts through which it circulates. This is very much the condition of the human embryo, when vessels are first developed

in it. The movement is towards the central spot, and is essentially capillary.

In the next higher class of animals we find provision made for a more vigorous circulation, in the endowment of the chief vessel with a contractile power. This is the case with the worm, in which the dorsal vessel may be seen in a constant state of alternate contraction and expansion. In the centipede and in insects, this dorsal vessel is divided into separate segments, by transverse partitions containing valves. Each of these cavities acts, to a certain extent, as a heart for a correspondent portion of the body, but they all participate in the general circulation. Sometimes several dorsal vessels may be seen at each side, uniting in front to form a single trunk, which runs backwards at the lower surface of the body, distributing the blood by lateral branches. The chief cause of the circulation here, is evidently not the contraction of the vessels, but the forces developed during the progress of the fluid, as in vegetables.

In Insects, the circulation is much less vigorous than in the other articulata; though it might have been expected, from the great rapidity and energy of their movements, that there would have been a corresponding activity of the circulation, for the purpose of affording a due supply of oxygen. This is provided for in another manner, the air being conveyed to the tissues, not through the blood, but through ramifications of the trachea and air-tubes, which penetrate to all parts of the body.

In the Mollusca there is a distinct heart, with muscular walls, having two separate cavities,—an auricle and ventricle. The ventricle sends the blood through the body in general; this is collected again, and transmitted through the respiratory organs, where it becomes aerated, either from the surrounding water, or from the atmosphere; and from these it is returned to the auricle, to be again sent through the system; hence the heart is merely systemic. In some of the lowest mollusks, there is observed a constant retrograde motion of the blood, after it has proceeded a certain distance; this appears to arise from a deficiency in the contractile power of the heart.

In Fishes the heart belongs to the respiratory system, since it is placed at the commencement of this system. It consists of one auricle, and one ventricle; the auricle receives the venous blood and transmits it to the ventricle, which sends it through the branchial arteries of the gills, there to be aerated by the action of the water; thence it is returned by the branchial veins to the aorta, which transmits it throughout the system. From the systemic capillaries, the blood from the anterior part of the body and head, proceeds immediately to the vena cava; but the blood of the posterior portion of the body, and of the abdominal viscera, goes to the liver and kidneys, where they minutely ramify so as to form the portal system; whence they collect again to join the vena cava, which empties into the auricle. Hence, in fishes, we perceive that *all* the blood is transmitted through the gills for aeration.

In Reptiles, whose motions are dull and sluggish, only part of the blood goes to the organs of respiration; hence, in them the heart contains two auricles and one ventricle. One auricle receives purely venous blood from the systemic capillaries, through the vena cava; the other receives purely aerated blood from the pulmonary capillaries, through the pulmonary vein. Both auricles discharge into one common ventricle, which consequently transmits blood of a mixed character to the various parts of the system; but which is sufficient to keep up the sluggish motions of these animals. The frog in its early or tadpole state, breathes like a fish, through the gills; but in proportion as it becomes developed into its more perfect condition, does the blood begin to be sent to the lungs; and at full maturity the gills are no longer serviceable. In some of the higher reptiles, as the crocodile, the single ventricle is arranged so as to transmit perfectly aerated blood to the head and anterior extremities, whilst mixed blood is sent to the posterior parts of the body.

In Birds and Mammalia, the circulation is distinguished by its complete double character. The heart, in them, may be considered as consisting of two distinct halves,—one a *systemic* heart resembling that of reptiles; the other a *respiratory* heart, resembling that of fishes,—each of which contains an auricle, and a ventricle. There is no direct communication between the two halves,—at least in the adult, though their walls are united for economy of space. In such animals, every portion of venous

blood becomes aerated in the lungs, before it is returned again to the heart for distribution to the system. A portion of venous blood—that which has traversed the walls of the intestines—is not returned directly into the vena cava, but is collected into a large venous trunk called *vena portæ*, which ramifies minutely through the liver, where the bile is secreted;—it is then collected again into the hepatic vein, to be finally emptied into the vena cava.

The Heart is formed, last of all, in the vascular system; and is only developed in its perfect state in the highest animals and in man. Its muscular power is greater in proportion to the extent of the circulation, hence it is greater in warm-blooded animals, in whom it appears to be the chief agent in the circulation. Some contend for its *exclusive* agency in the propulsion of the blood: this question will be examined when we reach the Capillaries.

Sect. 2. *Action of the Heart.*

The Heart is a hollow muscle, endowed with a great degree of *irritability*, by which it contracts and dilates alternately, under an appropriate stimulus. Its movements differ from those of other muscles in this: that, while in them, the individual fibres are in a state of alternate contraction and relaxation, when the whole muscle is in an active condition,—in the heart, the whole of the fibres of each division contract and relax *together*. Its contractile force is very great;—it cannot be prevented by the compression of the hand.

The usual stimulus of the heart's action is the *blood*, as is shown by removing the brain and spinal marrow, and keeping up artificial respiration, which maintains the circulation in the lungs. When the supply of aerated blood entirely ceases, the action of the heart stops; and this takes place much sooner in warm-blooded than in cold-blooded animals; thus the heart of a frog will continue pulsating many hours after its removal from the body, and that of the turtle, even after it has been cut into pieces. It is not, however, the mere contact of the *air* which causes the contractions to continue, when the heart is emptied of blood, since it will continue when a frog's heart is placed under the exhausted receiver of an air-pump.

The movements of the heart have been supposed to depend upon *nervous* influence. This is not the case, since they occur in acephalous monsters, and continue even after the brain and spinal marrow are destroyed, provided the destruction be not sudden. Again, they have been referred to the sympathetic system; but the facts above stated, showing that the heart's action will continue when taken out of the body, are sufficient to prove that no nervous influence is essential. Still, it is very much *influenced* by nervous action: thus Valentin found that when the heart had stopped pulsating, its action might be re-excited by irritating the spinal accessory nerve, or the first four cervical nerves. Irritation of the par vagum will excite it to increased action; but *both* trunks may be divided and very little distur-

bance ensue. The heart is excited, more, perhaps, through the ganglionic system of nerves—as by irritation of the cervical ganglia, particularly the first; and a case is recorded of very great diminution in its pulsations, causing extreme anxiety, produced by an enlarged bronchial gland pressing upon the cardiac nerve. It is believed that some cases of angina pectoris may depend on a lesion of the cardiac plexus. It is probably through the sympathetic nerve, that the heart is so much influenced by the *emotions*.

Any sudden or violent impression upon the nervous system may suspend, or even entirely stop, the heart's action, although there be no loss of nervous substance,—thus concussion of the brain, or a violent blow upon the epigastrium, which frequently causes instant death from the shock upon the large plexus of ganglionic nerves distributed over the viscera. Violent impressions upon other nervous expansions may also produce a great loss of the heart's energy; in this way a severe superficial burn may cause such a depression, particularly in cases of children, as shall prevent a reaction and produce death.

The contraction of the two ventricles, or their *systole*, is perfectly synchronous; so is that of the two auricles: but the systole of the auricles is synchronous with the *diastole* of the ventricles, or their dilatation. The regular succession of the auricular and ventricular contractions in the natural state, may be owing to the fact that the contraction of the auricle forces the blood into the ventricle, which is instantly

excited to contract by the presence of the blood,—its appropriate stimulus; and while the ventricle is contracting, the auricle, now free to dilate, is filled with blood from the veins; and the stimulus of this blood causes contraction of the auricle, just when the ventricle has ceased contracting and is ready to receive the contents of the auricle. The *duration* of the systole is double that of the diastole. There is hardly any pause between the different acts of the heart, when they are vigorously performed;—the contraction of the auricles commences at the insertion of their veins, and is thence extended throughout. The ventricular systole propels the blood through the aorta and pulmonary artery; and it also corresponds with the *pulse*, and with the *impulse* of the heart against the chest, (between the cartilages of the fifth and sixth ribs.) This impulse is produced by the peculiar manner in which the systole takes place;—though the ventricle contracts in every direction, its shortening is most obvious; and owing to the spiral arrangement of its fibres, its apex is made to describe a spiral movement, from right to left, and from behind forward.

The *diastole* is not a mere passive movement,—as is shown by the great force it is capable of overcoming. The diastole consists of two movements,—the fall of the heart backwards, and its sudden dilatation in every direction. Between these two movements there is a brief interval of repose.

These movements of the Heart are accompanied by certain sounds, called the "Sounds of the Heart,"

which are valuable as diagnostic signs. They are named the *first* and *second* sounds. The first is produced by the ventricular systole, and is synchronous with the pulse: it is dull and prolonged. The second is short and sharp, and follows immediately after the first; and it must be caused during the first stage of the ventricular diastole. It is followed by a brief interval of repose, during which the second part of the ventricular diastole, and the auricular systole occur. If the interval between two beats of the heart be divided into four parts, two will be occupied by the first sound; one by the second; and one by the interval of repose.

Cause of the Sounds. Laennec attributed them to the alternate contraction of the ventricles and auricles;—this is not correct. The first sound depends upon several causes: 1. The impulse against the thorax, since, when this impulse is prevented, the sound is fainter; but it is not exclusively due to this, since the sound has been heard when the heart was outside of the body. 2. To the rush of blood through the orifices of the aorta and pulmonary artery. This is proved by the occurrence of any obstruction at these orifices, by which both the intensity and prolonged character of the sound are increased; a similar sound, "bruit de soufflet," may be heard with the stethoscope, by compressing any large artery so as to narrow the calibre. 3. The friction of the muscular fibres,—since every muscle produces some sound in contracting.

The second sound is more simple—being due to

the *click* produced by the sudden filling out, and closure of the semi-lunar valves of the aorta and pulmonary artery, just as the diastole of the ventricle is commencing, and the blood has a tendency to regurgitate into it again. There is no difference of opinion upon this point. If one of the semi-lunar valves be hooked back, no sound is heard; and if their complete closure be prevented by disease, the sound is either lost, or very much diminished; hence its value in diagnosis. The reflux of blood, in this case, is indicated by a *prolonged* second sound, similar to the first.

The movements of the auriculo-ventricular valves (tricuspid and mitral,) commonly occasion no sound, because their closure is more gradual than that of the semi-lunar valves—as they are restrained by the chordæ tendineæ. But when these valves are diseased, they may give rise to morbid sounds. The columnæ carneæ merely give stability to the margins of the valves: they exert no active influence.

In health, no sound is produced by the opposite surfaces of the pericardium rubbing together, as they are moistened by serum; but in inflammation of this membrane, when it becomes dry or roughened, a *friction* sound is heard.

The tricuspid valve does not close so completely as the mitral; hence there is a partial retrograde motion into the right auricle, which accounts for the *venous* pulse seen in the jugular veins of some persons. It is a wise provision, intended to guard against over-distention, which is very apt to occur,

and which would produce paralysis of the ventricle. Hence, in asphyxia, bleeding from the jugular vein may prove of great benefit.

The walls of the four cavities are of different thickness. That of the *left ventricle* is greatest, because it is obliged to exert a greater contractile force. The average is about four and a half lines; it is greatest near the middle. The average thickness of the right ventricle is one and a half lines, being greatest at the base. The left auricle is somewhat thicker than the right—being, according to Bouillaud, one and a half lines.

The *capacity* of the four cavities is very nearly the same, being about two ounces. The ventricles are a little the largest.

The quantity of blood propelled at each contraction of the ventricles is nearly two ounces; since they do not completely empty themselves. Now, taking the whole amount of the blood to be one-fifth of the weight of the body, it will amount to twenty-eight pounds in a person weighing one hundred and forty pounds. Allowing seventy-five pulsations to the minute, we shall have one hundred and fifty ounces, or nine pounds, six ounces, passing through the heart in each minute; and consequently about three minutes would be required for the whole of the blood to pass through the heart, on the supposition that the circulation was governed entirely by the heart's action. But actual experiment shows a much more rapid circulation than this; for a saline solution injected into the jugular vein of a horse,

was detected in the carotid artery of the opposite side, in twenty seconds. A saline solution injected into the jugular vein of another horse, was detected in the veins of the lower extremity, in a little over twenty seconds. Hence we must conclude that the *rapidity* of the circulation is due to some other than the heart's action.

The propelling force of the heart was estimated by Hales: by inserting a long pipe into the carotid of a horse, he found the column would sometimes rise as high as ten feet. By comparative experiments, he estimated the force of the human heart to be capable of supporting a column, in the aorta, $7\frac{1}{2}$ feet high, the weight of which would be $4\frac{1}{2}$ pounds. Another method was adopted by Poisseuille—by means of an instrument called a hæmadynamometer, which consisted of a bent tube containing mercury, one leg of which was horizontal: the horizontal portion being inserted into the artery, the propulsive force was measured by the height to which the mercury rose in the tube. The result very nearly corresponded with Hales',—being $4\frac{1}{3}$ pounds. But the true measure of this force is estimated by multiplying the pressure in the aorta, into the surface of a plane passing through the base and apex of the left ventricle; by which calculation, it is found to be 13 pounds.

SECT. 3. *Action of the Arteries.*

The arteries are simple hydraulic tubes for transmitting the blood to the various parts of the body.

The ancients supposed them to be air-tubes to convey air into the interior of the body. The blood flows into the arteries in successive jets, owing to the contractions of the heart; and this interrupted character of the flow would continue, if it were not equalized by these vessels. Their *middle* or *fibrous* coat, consists partly of a yellow elastic tissue, and partly of a non-striated muscular fibre. The elastic tissue predominates in the larger arteries; the muscular in the smaller. The elasticity of the arteries is the chief cause why the blood is propelled in a continuous stream. Thus, if a forcing-pump be adjusted to an elastic tube, although the fluid is forced in by successive jets, it will issue from the other end in a continuous stream. The elasticity of the arteries is not absolutely indispensable; since it is lost in ossification of the vessels, in old people; but in such persons, very slight causes may produce death. Under the impulse of the heart, the arteries dilate both in their length and breadth; the increase in the length is greatest, which causes the vessel to be lifted up from its seat. The transmission of the pulse-wave through the whole system is not instantaneous, but takes place in an appreciable time. The pulsation of the large arteries near the heart, is synchronous with the systole of the ventricle; but that of the smaller and distant arteries is later, varying with the distance, and amounting sometimes to the one-sixth of a second.

The muscular contractility of arteries has often been denied. Numerous experiments, however,

prove its existence:—such as their contraction under the application of stimuli to their walls;—the fact, that when an artery is dilated with blood thrown into it by the heart, it reacts with a force *greater* than the impulse;—also, if a portion of an artery from an animal recently dead, in which the contractile power is yet preserved, and a similar portion from an animal that has been dead some days, and in which the *elasticity* only remains, be distended, with equal force, the reaction of the former is much greater than the latter. The object of this contractile power of the artery, is to assist the heart in the propulsion of the blood. It may serve to make up for the loss of power occasioned by the friction of the blood against the sides of the vessels. If an artery be twisted, or violently torn, hemorrhage is usually prevented—probably by its contractility being destroyed, in consequence of the injury done to the coats of the vessels preventing the subsequent expansion.

The power which the arteries have of adapting themselves to the quantity of blood to be transmitted, seems to be due to their muscular contractility. This is seen in the case of the uterine and mammary arteries during pregnancy and lactation; also in diseases attended with increased action of particular organs. In such cases it cannot be the *vis a tergo* of the heart, that causes the enlargement, since this would necessarily affect all alike. It must be due to a power inherent in themselves; and it is probable that the sympathetic nerve controls this

power, and distributes the blood according to the wants of the system.

The relative capacity of the arteries is very nearly the same in every part of the body: that is, if a section were made through all the systemic arteries at any given point, their united areas would be equal to that of the aorta, although the diameters of the branches at each subdivision, together exceed that of the trunk. But the calibre of a tube is estimated by its *area*, and not by its diameter; and the areas of circles are as the squares of their diameters. Hence the comparison must be made between the *square of the diameter* of the trunk and the *sum of the squares* of those branches. Thus, an artery whose diameter is 7, may subdivide into two branches, each of which may have a diameter of about 5, and yet their *areas* be alike; for the square of 7 is 49, and twice the square of 5 is 50; and so on with other examples.

The object of the frequent *anastomoses* between the arteries is to ensure the continuance of the circulation, in case of the main trunk becoming obstructed. This is seen in the operation of tying an artery in aneurism, when the supply of blood, which was at first cast off, is very soon restored through the collateral branches, which become very much enlarged; while the main trunk is usually found to have become quite impervious above the ligature up to the first anastomosing branch.

The *Pulse* is produced by the propagation of the ventricular contraction through the arteries by

means of the wave of the blood. It is not perfectly synchronous in every part of the body. If the column of blood be interrupted by any obstacle, as by an aneurismal tumour, or if the blood does not completely fill up the calibre of the vessel, the pulse is not fully developed; there must be full *tension* of the coats of the vessel, as well as a due *tonicity*. If the tube were not elastic, the mere contraction of the heart could produce no pulse; and if it yielded too much to the distending force, this force would be expended upon the sides of the vessel, and the movement of the blood would be arrested, or would proceed very slowly. So again, there must be a certain resistance in the capillary vessels, since, if this be taken off, the arteries empty themselves, and the pulse ceases.

The pulse is liable to great variations within the limits of health. The chief influences are the following:

Age. In the fœtus* it averages from 140 to 150 beats in a minute; at birth it is about 130; at one year, 115 to 120; at 7 years, 85 to 90; at puberty, 80 to 85; at manhood, 70 to 75. It gradually declines to old age, when it is from 40 to 60.

Sex. In females, the pulse is usually from 10 to 15 beats more frequent than in men. It is also more liable to disturbance.

Temperature. Increase of temperature produces an increase of the frequency of the pulse.

* Dr. Valleix has lately stated, that at birth the pulse is less frequent than at six months.

Muscular exertion always accelerates the pulse. Posture exhibits the effects of long-continued muscular exertion, upon the pulse: thus, in the standing posture it will beat 7 to 10 strokes faster than in the sitting position, and 4 or 5 strokes faster in the sitting than in the recumbent posture. Hence the patient's pulse should never be examined while *standing*, particularly if under the effects of digitalis, which powerfully depresses the action of the heart. The difference in position is most striking in very feeble persons. The pulse is also more frequent in tall and thin persons, than in those who are short and fat.

The *Mental emotions* produce a powerful influence on the pulse, particularly in females. It is familiarly witnessed in the effects produced by the mere visit of the physician, upon the pulse of nervous patients of either sex. Hence the rule, always to wait a little while before ascertaining the state of the pulse. The *intellectual* operations do not appear very sensibly to affect the pulse unless a state of feverishness be induced. During *Digestion*, the pulse is rather quickened;—it is rather more frequent in the morning than in the evening.

The pulse is either increased in frequency in enfeebled health, or is very easily accelerated: on the contrary, it becomes slow and full as the energy of the system increases. Hence we have a golden rule for the administration of tonics and stimulants.

The pulse is not to be regarded as an index of the

condition of a *single* organ, but of a variety of organs as, (1.) Of the heart, as respects its force, regularity, slowness, &c. (2.) Of the aortic valves;—disease of them may be suspected when there is a strong impulse of the heart attended with a feeble pulse, or if the pulse is very irregular, while the action of the heart is regular. (3.) Of the quality of the blood;—when it is thin and watery, the pulse is full and gaseous and easily compressible: such a pulse is easily excited. (4.) Of the condition of the arteries;—the pulse is *soft*, when their contractile power, or *tonicity*, is enfeebled. (5.) Of the state of the capillary circulation;—thus in an inflammatory or congestive stasis in the capillaries, we have resistance, causing a distention of the arteries and a more bounding pulse; but when their vital activity is diminished, we have a more feeble pulse; and when they are nearly emptied, the pulse almost ceases to beat. (6.) Of the condition of the nervous system—as noticed above.

Sect. 4. *Action of the Veins.*

The Veins are formed by a reunion of the small vessels in the capillary rete. They carry the blood back to the heart. The systemic veins circulate black or venous blood; the pulmonary veins, arterial blood.

The structure of the veins is very similar to that of the arteries, but their middle coat possesses less contractile power. The whole capacity of the ve-

nous system is estimated at two or three times that of the arterial ; consequently the rate of movement in them must be proportionally slower.

The veins are distinguished by their *valves,* which are formed of duplications of their lining membrane, and intended to prevent a reflex movement of the blood. There are no valves, however, in the *vena portæ.*

The circulation in the veins depends chiefly upon the contractile force of the heart and arteries. Experiments show that a power less than that of the heart, is sufficient to drive the blood through the veins.

Other causes, however, contribute to the circulation, as 1. the movement of inspiration, which produces a partial vacuum in the chest, and thereby favours the current of blood *towards* the heart, causing the respiratory pulse seen in the veins of the neck in thin persons. This is also proved by the experiment of inserting a tube into the jugular vein of an animal, the lower end being dipped in water; at each inspiration, the water was drawn up into the tube. 2. Muscular movements;—each movement will cause some of the veins to be compressed; and since the blood is prevented by the valves from going backward, it must be propelled *towards* the heart. Hence, sudden and violent exertion is very dangerous in cardiac diseases, in consequence of the impetus of the blood. 3. The partial regurgitation from the ventricle into the curricle, during the ventricular systole. This occurs whenever there is an over-dis-

tention of the heart, resulting from some obstruction to the circulation through the lungs, as in chronic dyspnœa, &c.

Gravity appears to have much more effect upon the venous, than upon the arterial circulation, chiefly on account of the less amount of tonicity in the former,—as may be proved by experiment out of the body. Hence we can understand the cause of œdema arising in relaxed debilitated states of the system, where, the venous circulation being particularly influenced by gravity, the watery parts of the blood transude through the vessels. The *varicose* veins of the leg are often attributable to a similar relaxed condition. The influence of gravity is also seen in the beneficial effects produced by proper position upon an inflamed limb, so as to drain it of blood. As before mentioned, the veins have the power of absorption.

SECT. 5. *Action of the Capillaries.*

The Capillaries are the minute vessels intermediate between the arteries and veins. They are spoken of as a *rete* or net-work, on account of the closeness and intricacy of their inosculations. Though extremely delicate in their texture, they have distinct walls. The form of the capillary rete is different for each organ of the body, so that a portion of the minutely injected capillaries would suffice to enable the anatomist to determine from what structure it had been taken;—thus, there is one sort for the muscle, another for a mucous mem-

brane, a third for a follicular mucous membrane, a fourth for a nervous centre, a fifth for the papillæ, &c.

The smallest capillaries will admit but a single file of blood-corpuscles; the larger ones admit two or three. They are constantly undergoing a variation in size, sometimes contracting and sometimes dilating.

As respects the question whether there are capillaries which circulate only *white* blood, as in the white tissues,—the probability is that they are only the common capillaries in a state of extreme contraction, circulating but a single file of corpuscles, which, under the microscope, appear nearly colourless;—hence the white tissue may *appear* to be destitute of red blood, from the small number of capillaries which they contain.

The great object of the capillary circulation would seem to be to bring the blood in a finely divided state, in relation with the minutest parts of the organs, so as to present the conditions most favourable for the functions of nutrition, secretion and aeration of the blood;—thus, for example, in the lungs, by the extreme minuteness of the capillary rete, a very considerable surface is brought into relation with the inspired air, and thereby a large amount of oxygen taken in, and carbonic acid given out at each movement of respiration. The same is true of the other functions.

The movement of the blood in the capillaries depends upon several causes. In the first place the

contractile force of the heart extends through them; for when this becomes weak or irregular, a considerable change is manifested in the capillary circulation. On the other hand, the capillaries evince a power *in themselves* of greatly controlling the circulation of the blood in them. This is manifested by observing the capillary circulation in a transparent tissue—as the web of a frog's foot, when constant changes may be noticed; some tubes may be seen enlarging so as to admit several files or corpuscles, which before were only large enough for a single file; and others will become apparently obliterated, from their extreme contraction. Again, the velocity of the blood in the capillaries is by no means uniform, even where there is no interruption to the heart's action; for frequently an entire stagnation will occur, and even a change in the direction of the current. In the lowest animals, as well as in vegetables, we know that the circulation is maintained in the minute vessels, without the aid of a heart, and indeed entirely independent of any *vis a tergo*, but by some power closely connected with the state of their nutritive and secretive processes. The same is true as we ascend the animal scale, though the *capillary power* becomes modified very much by the force of the heart. Still, in cold-blooded animals, the movement of the blood in the capillaries has often been seen, after complete excision of the heart; and although the same experiment cannot be performed on warm-blooded animals, in consequence of the severity of the opera-

tion, it may be proved to occur in them in other ways. Thus, after a natural death, the arteries are found to have emptied themselves completely in the course of a few hours: the mere *tonicity* of the vessels is not sufficient to account for this, hence the inference that the capillary circulation must have continued. Further, it is known that a real secretion continues after death, which we know would be impossible without the capillary circulation. In the development of the vascular system in the embryo, the first movement of the blood is always *towards*, instead of *from* the centre.

The true principles which regulate the capillary circulation are believed to be essentially the same as those which govern the circulation of the sap in vegetables; and which have been explained by Prof. Draper. If two liquids be made to communicate with each other through a capillary tube, for which they have an unequal affinity, a movement will ensue; the liquid which has the strongest affinity being absorbed most rapidly into the tube, driving the other before it. The same is true, if instead of a single tube, a network of tubes, or a porous substance, be used; the liquid with which it may be saturated will, as in the former case, be displaced by another for which it has a greater affinity. Now to apply this to the circulation of the sap in vegetables, or of the blood in the capillaries: the different parts of the structure have an affinity for different materials in the circulating fluid; such materials are appropriated to those particular parts, thus, the dif-

ferent cells, by virtue of their selecting power, attract the peculiar matters of their growth or secretion; and the circulating fluid having given up these materials, has no longer the same affinity for these particular parts which it had before, and it is consequently driven from them by the superior attraction then exerted by a new portion of fluid, which is destined, in like manner, to be replaced by another portion, and so on. For example, the blood, having just been charged with oxygen in the lungs, and become *arterial*, has a greater affinity for all the tissues through which it circulates, than venous blood, which has already parted with its oxygen and become charged with carbonic acid. Consequently, upon the principle just mentioned, the arterial blood entering the capillaries on one side, must drive out on the other the blood which has become venous. In the capillaries of the lungs, on the other hand, we have opposite affinities at work. Here the attraction is between the venous blood and the air, from which results the interchange between them of oxygen and carbonic acid; but when the blood has thus become arterialized, the same attraction no longer existing, it is driven onwards by the venous blood behind it. But suppose the supply of oxygen to be cut off from the lungs, so that the blood is no longer aerated,—then, the attraction no longer existing between the venous blood and the pulmonary capillaries, there is nothing to push it forward through the pulmonary veins into the left side of the heart; hence a *stasis* takes place in the lungs, producing the phenomena of asphyxia.

Thus we are enabled to understand how the rapidity of the circulation in a part will depend upon the *activity of the functional changes* going on in it, whilst the general circulation remains unaltered. For when the nutrition of a part is increased, or when it is stimulated by exercise, a larger amount of blood must pass through it in a given time, in consequence of the affinities being stronger, and more rapidly satisfied; and this may occur without any enlargement of the calibre, although the arteries which supply the part soon increase in size, in order to supply the increased demand. From this well known fact, we have the aphorism "ubi stimulus ibi fluxus." Such a condition is known as *active congestion*, or *determination of blood*, and is dependent upon an undue functional activity on the part. This state is generally the precursor of *inflammation;* but it differs from it in not consisting in any alterations in the function, but only an exaltation. It is frequently observed in persons of very active minds, when the function of the brain is unduly tasked; the excess of blood sent to the head, is seen in the suffused countenance, pulsation of the carotids, together with the coldness of the lower extremities.

Another opposite condition of the capillaries, is also met with, termed *passive congestion*, in which the functional energy is deficient, and the circulation through the part is consequently retarded. This condition, as well as the preceding, predisposes to inflammation, though in a different mode. Such

a congestion is relieved by any thing which promotes the action of the part: thus, congestion of the liver is removed by remedies which increase its functional activity, as mercury.

The influence exerted by the nervous system over the capillaries, though not essential, is nevertheless very manifest—especially that part through which the emotions act. This is familiarly seen in the act of *blushing*, which depends upon a sudden enlargement of the capillaries of the face, under the influence of some emotion. So also the opposite state of *pallor*, which depends upon a sudden contraction of the same capillaries under the influence of a strong emotion, as fear. The same thing is also seen in certain glands, as the *mammary*, in which the amount of the secretion is increased through the increased quantity of blood sent to the parts. In this manner "the draught," as it is termed by nurses, is occasioned by the emotion excited by the sight, or even by the thought of the child. It is witnessed also in the salivary and lachrymal secretions. The *quality* of these secretions, which is also altered, as well as their amount, probably depends upon some changes produced in the blood itself through the agency of the nervous system.

Although the capillary circulation, as we have seen, occurs independently of the nervous system, still, as in the case of the arteries, any sudden or violent impression upon the great nervous centres, will bring it to an immediate stand.

CHAPTER IX.

OF RESPIRATION.

Sect. 1. *Nature and Object of the Function.*

The essential object of the function of Respiration is to free the blood from carbonic acid, and to introduce into it oxygen from the surrounding medium. The necessity of this function to *all* organized beings, is inferred from the fact, that every plant and animal exhibits it, though in different modes.

The respiration of vegetables is precisely similar to that of animals; that is, they are constantly giving off carbonic acid, and absorbing oxygen. But this process is frequently not obvious, in consequence of another function which they perform, namely, that of the fixation of carbon, by decomposing the carbonic acid of the air, appropriating the carbon as their food, and liberating the oxygen. This last process is the *digestion* of plants, and is accomplished by the leaves, and only under the stimulus of solar light; whilst the process of respiration goes on as well in the dark as in the light. A healthy plant will, however, *fix* much more carbon than it sets free by respiration, so that the general effect of vegetation is to purify the atmosphere from the carbonic acid produced by animal respiration, combustion, &c.

The necessity of respiration in animals is still

more evident. The *feeling* appears to be an instinctive one, and although very partially under control, yet in the higher animals, and in man, it becomes in a few minutes irresistible,—the *will* ceasing to be able to prevent the inspiratory movement. If the admission of air into the lungs be prevented by any means, the respiratory efforts become at first very violent; these are followed by irregular convulsive movements, which shortly terminate in insensibility, producing asphyxia. This condition generally comes on, in warm-blooded animals, within ten minutes; but in the cold-blooded, a much longer suspension may be borne with impunity, and even by warm-blooded animals in the *hybernating* condition, by which the activity of these functions is much reduced.

It is not so much the want of the introduction of oxygen into the lungs, as of the excretion of carbonic acid from them, that proves the source of difficulty in asphyxia; this latter agent seeming to exert a directly poisonous effect upon the system, if not properly eliminated. The source of this carbonic acid in venous blood is three-fold. In the first place, as has been already shown, all the various acts of life in the animal are attended by a waste or disintegration of the different tissues. One of the products of this decomposition is carbonic acid;—this is the ordinary waste of the tissues. A second source of carbonic acid in venous blood, arises from the rapid changes which take place in the muscles and nerves during their period of activity; these changes

being in exact proportion to the degree of this activity. Now oxygen is indispensable, both for muscular and nervous action; and from its union with the elements of tissue, carbonic acid among others, results. In those animals whose muscular and nervous structure are comparatively small, the amount of carbonic acid generated, is proportionally minute; but whenever we find the muscular powers well developed, we invariably have a large amount of carbonic acid set free by the lungs. This is well seen in insects, some of which are remarkable for their muscular powers: thus, a single humble-bee was found to produce as much carbonic acid in the course of one hour, during which it was in a state of violent excitement from its capture, as it did afterwards, when calm, in the course of twenty-four hours. The third source of the carbonic acid is due to animal heat, which is peculiar to warm-blooded animals, and depends upon the combustion of most of the oily materials of the food,—they entering into distinct combination with oxygen, and producing carbonic acid as the result.

The amount of carbonic acid produced directly from the elements of the food, will vary very much in different animals, or in different states of the same animal. Thus, in the carnivora, which are generally very active, the greatest part of it is derived from the waste of the tissues; whilst in the herbivora, which are inert and sluggish, the quantity derived from this source is far from enough, and hence much of their food is appropriated as *fuel* for

the generation of animal heat, so as to supply the deficiency. In man, and other animals capable of a diversity of habits, we find both sources in operation,—one serving as the complement of the other. When the external temperature sinks, the direct combination of the food with oxygen will be increased in order to supply the deficiency; and whenever the supply of food is too little, the fat, which has been stored up, is drawn upon, and if this be exhausted, the animal dies of cold.

The two-fold effect of the introduction of oxygen into the lungs, and the extrication of carbonic acid from them, is accomplished by the same act of respiration, by virtue of the law of endosmose, or the "mutual diffusion of gases." Thus, if a bladder containing venous blood be suspended in a receiver containing oxygen, the blood will soon assume the arterial hue, in consequence of the carbonic acid passing out through the membrane, while oxygen passes in, just as two liquids of different densities would act. This is precisely the condition in the respiratory organs of animals: by means of the minute ramifications of the pulmonary capillaries, an immense surface of blood is brought into relation with the atmospheric oxygen,—a delicate membrane only being interposed, which, as we have seen, offers no resistance to their mutual transmission.

Such, then, is the *essential* part of the function of respiration; but the dynamic forces of the heart and of the muscles of respiration are also requisite —the former to supply the constant renewal of

blood to the pulmonary capillaries; the latter to ensure the requisite supply of air in the pulmonary vesicles.

Sect. 2. *Different Forms of the Respiratory Apparatus.*

In the very lowest order of animals inhabiting the water, there is no special organ of respiration; the integument serving the purpose of an aerating membrane, through which, the air contained in the liquid comes in contact with the fluids of the body. The renewal of the fluid in contact with the animal, is accomplished by means of *cilia*, which appear also to serve as organs of prehension and locomotion. Sometimes also the internal prolongation of the integument—its stomach,—acts as the aerating membrane, the air being furnished from the water which fills the cavity.

In the mollusca there are distinct organs of respiration. As most of them are aquatic, they are furnished with *gills*, which differ a good deal in their complexity. In these, also, the constant renewal of the water is provided for by *ciliary* movement. In the land mollusks, as the snail, there is usually a simple cavity situated in the back, communicating directly with the air through an aperture in the skin, and having a net-work of vessels on its walls.

In many of the lower articulata the respiration is carried on through the tegumentary membrane,—as in the tape-worm. In the marine worms there is a

series of gill-tufts along the body, in which the blood is brought into relation with the surrounding medium. The crustacea, as the crab, breathe by gills, which are enclosed within a sort of doubling of the shell on the under surface of the body; and a constant stream of water is maintained through this. The land-crab has also gills, though it is an air-breathing animal; the proper amount of moisture necessary for the play of the gills being provided for, by means of an apparatus within the gill cavity.

In insects, the respiratory organs consist of a number of small sacs, called *spiracles*, distributed along each side of the body, and communicating with two tubes called *tracheæ*, which extend the whole length of the body. Occasional dilatations are met with in these tubes, which act as reservoirs for air in those insects which make long flights, so as to diminish the specific gravity of their body.

The gills of fishes resemble, essentially, those of mollusks, but they are much more perfect. The water is first taken in at the mouth, then forced, by muscular contraction, through an aperture on each side, into the gill-cavity. Here, the aerating process takes place, after which the water is expelled through the outward openings at the back of the neck. The reason why fishes die so soon when taken from the water, is chiefly, on account of the drying up of the membrane of the gills by the air, preventing thereby the aeration of the blood; and also on account of the flapping together of the filaments of the gills, by which a sufficiently large surface is prevented being

exposed to the air. Hence we find those fishes living the longest, in which the external gill openings are very small.

Very often, the supply of air in the water is not sufficient for fishes;—this causes them to rise to the surface, and swallow air, which passes into the intestines, the surface of which appears to act as a respiratory membrane. The *air-bladder* in fishes, has often no connexion whatever with their respiratory apparatus, being entirely closed. It seems designed to regulate their specific gravity. In other cases, however, it forms a communication with the intestinal canal, and is thus concerned in respiration.

In reptiles, although the lungs are large sacs, yet from their not being much subdivided, but a small amount of surface is exposed;—this is in character with the low activity of their functions. These lungs are not filled by the mere act of inspiration, as in other animals, but by an act of swallowing; a single inflation thus made, being sufficient to last the animal a considerable time. When the air thus taken in has become exhausted, it is returned by the aid of muscular pressure, and its exit through their narrow glottis, is accompanied by their peculiar *hissing* noise.

In birds, whose respiration is very active, the lungs are minutely subdivided, and likewise communicate with air-sacs placed in different parts of the body, and in most birds, with the cavities of the bones, the lining membrane of which, serves as an

aerating surface. This arrangement also diminishes their specific gravity, and facilitates their flight. The natural condition of the lungs of birds is that of distention; in consequence of the elasticity of their tissue, it requires muscular power to empty them.

It is in the mammalia, and in man, that we find the respiratory apparatus most complete, and the ultimate divisions of the lungs most minute. The lungs are suspended in a perfectly closed cavity—*the thorax*,—with the sides of which they are, under ordinary circumstances, always in contact. The capacity of the thorax, however, is susceptible of great change under the action of the intercostal and abdominal muscles, and diaphragm. When the chest is expanded by muscular action, the air within the lungs, by virtue of its elasticity, causes them to dilate, so as to fill up the vacuum thus created; and this immediately causes the air to rush in through the trachea. The complete dependence of the expansion of the lungs, upon the perfection of the vacuum of the chest, is well shown by the effects of admitting air into the pleural cavity, either by an external opening, as a punctured wound, or by internal communication formed between the lungs and pleural cavity: in either case, instant collapse of the lungs takes place; and if it occurs in both sides, asphyxia results. The expulsion of the air from the lungs is caused chiefly by the elasticity of the cartilages of the ribs.

The muscles of *inspiration* are the scaleni, the intercostals, and the diaphragm; the elevation of

the ribs being also assisted by some of the muscles of the scapula. But in ordinary tranquil breathing, the diaphragm is the chief agent of inspiration; its contraction producing a change in its position from its highly arched shape, to nearly a horizontal one. This enlarges the cavity of the thorax, and at the same time presses upon the abdominal viscera, causing them to protrude forward. The movement of *expiration* is effected by the contraction of the abdominal muscles, aided by the elasticity of the cartilages of the ribs.

The larger bronchial tubes are cartilaginous. The smaller ones are not believed to be so, although retaining their circular form; they possess, however, decided contractility, which is probably due to a fibrous structure, having the properties of the non-striated muscles. This contractility may be called into action by various stimuli applied directly to their walls, though not readily by stimulating their nerves. The disorder termed spasmodic asthma, consists in a spasmodic contraction of the minute bronchi, dependent often upon remote causes. This is confirmed by the fact that the contractility of these parts is much diminished by certain narcotics, as belladonna and stramonium, substances which are well known to be beneficial in the treatment of this affection.

The diameter of the ultimate air cells of the human lung varies from the 1-200th, to the 1-70th of an inch. Their form is irregular—their walls being flattened together. Each ultimate bronchial tube

terminates in a cluster of these vesicles, every one in the group thus formed, freely communicating with its fellow,—all being lined with a continuation of the lining membrane of the bronchus. Between the air cells there is a delicate fibrous tissue of an elastic character. It is through these minute air-cells, that the blood comes into relation with the air,—the extremely minute capillary plexus of the pulmonary artery being placed between the walls of the air-cells, so that the blood in them is aerated on both sides. It has been calculated that each ultimate bronchus terminates in about 18,000 air-cells, and that the total number of these cells in the lungs amounts to six hundred millions. And so intricate and minute is the capillary plexus, that Munroe calculated that there was a superficies of vascular surface exposed to aeration, equal to several hundred square feet.

Sect. 3. *Mechanical Effects of Respiration.*

At each respiration, only a portion of the air within the lungs undergoes a change. It is estimated that about twenty cubic inches of air are inhaled at each inspiration, the same amount being also given out at every expiration; and that about one hundred cubic inches remain in the lungs after ordinary expiration.

Some late experiments of Mr. Hutchinson go to show that there is a pretty certain ratio between the capacities of respiration and the height of the individual—the capacity uniformly increasing with the

height, so that for every additional inch of height, from five to six feet, eight additional cubic inches of air are given out by a forced respiration. In fat persons, the capacity is lower than in other.

The average number of respirations per minute in a healthy adult, is from fourteen to eighteen. The most of these are performed simply by the diaphragm, but at about every *fifth* inspiration, a more decided movement occurs, attended with an elevation of the ribs. The frequency of the respiration is liable to great modification from various causes—as exercise, emotion, action of narcotics, apoplexy, &c. It is always accelerated by diseases which interfere with the function of the lungs—as pneumonia, pleurisy, &c. Thus, while the usual proportion between the respiration and the pulse, is as one to four and a half or five, it may become in pneumonia, as one to three, or even one to two. The same acceleration takes place also where other parts concerned in the mechanism of respiration are affected, as the pleura, the ribs, the muscles, (as in rheumatism,) the abdominal viscera, and the peritoneum. In all these cases, the deficiency in the amount of the respiratory movements is attempted to be made up by their frequency.

As already shown, the movements of respiration are involuntary, to a great extent at least, being performed through *reflex* action. The great centre of these movements is the medulla oblongata,—particularly the corpus olivare, which might be denominated the *respiratory ganglion*. The brain may be removed, as well as the spinal cord, below the

medulla oblongata, and respiration will still go on. The chief excitor or *afferent* nerves, are the par vagum, which conveys the impression from the lungs themselves, and the sensory branches of the fifth, which convey sensations from the general surface. This is well seen in the first efforts made to breathe by a new-born-child, and in the effects of cold water suddenly thrown upon the surface, and of irritation of the skin in cases of narcotic poisoning. The *efferent* or motor nerves are chiefly the phrenic and intercostals.

It is to the *limited* control which the will has over the respiratory movements, that the faculty of speech, and its modifications of singing, &c., are due.

So long as the function of the medulla oblongata is not interfered with, respiration will go on; thus it proceeds with perfect regularity in sleep, because the medulla oblongata is always active, though the brain may be perfectly quiescent. In apoplexy and in narcotic poisoning, the breathing becomes affected because the influence is gradually extended from the brain to the medulla oblongata. When the respiration becomes suspended from the effects of narcotics, life may often be saved by resorting to artificial respiration, by which the circulation may be kept up until the poison has passed off from the system.

In typhoid fever, the respiration becomes very much reduced in frequency—probably from a poisonous effect produced on the blood, which, in consequence, does not stimulate the nervous centres to a sufficient degree.

SECT. 4. *Chemical Effects of Respiration.*

It was formerly supposed that the venous blood arrived in the lungs charged with carbon, and that here a union was effected between this and the oxygen of the air, which was the source of the carbonic acid exhaled. This idea, however, is no longer tenable, since it is proved that carbonic acid will be given out from the lungs, if an animal be made to breathe pure hydrogen or nitrogen. The true statement is, that the venous blood is charged with *carbonic acid*, which is formed in the systemic capillaries; and that, in the lungs, this carbonic acid is displaced by the oxygen absorbed. The atmosphere is composed of about twenty-one per cent. of oxygen by measure, and seventy-nine of nitrogen, or over three-fourths: the only office of the nitrogen being, so far as known, to dilute the oxygen.

The relative proportions of oxygen absorbed and of carbonic acid given out, though not invariably the same, may be stated to follow the general law of the "diffusion of gases," which is, (according to Brunner and Valentin,) that they are inversely as the square roots of their specific gravities. This law, applied to the case of oxygen and carbonic acid, gives us the proportion of 1174 to 1000, which corresponds very closely with the relative proportions of these two gases interchanged in respiration. From this it will be seen, that as there are 1174 parts of oxygen taken in, and 1000 parts thrown off in the form of carbonic acid, there will remain

174, or nearly 15 per cent. to be accounted for in other ways. Some of this oxygen combines with the sulphur and phosphorus of the body, to form sulphuric and phosphoric acids, which again unite with bases to form salts; and some of it unites with the hydrogen of the oily matters to form water, which is exhaled from the lungs.

The actual amount of carbonic acid exhaled during a given time, varies according to several circumstances:—as age, sex, temperature, period of the day, and exercise. The average quantity exhaled in twenty-four hours is about 17,856 cubic inches; this will contain 2,616 grains, or 5½ ounces of solid carbon. According to Prof. Scharing's accurate experiments, the total amount of carbon set free from the system, both by the lungs and skin, in 24 hours, is from 7 to 8 ounces. The amount of carbonic acid exhaled is very much increased by a reduction of temperature; thus, at 32° it is more than double what it is at 100°. Exercise also augments it, whilst sleep diminishes it: thus a person who was excreting 145 grains of carbon per hour, while fasting and at rest, excreted 165 after dinner, and 190 after breakfast and a walk; but only 100 when asleep. The exhalation is also greater in males than in females of the same age, except in childhood. In males the quantity increases regularly from eight to thirty years; it then remains stationary till forty; after which it regularly diminishes to extreme age, when it is not greater than at ten years. Great muscular development, however, will always cause the amount

18

excreted to exceed this average, while a deficient development will produce a diminution of it. In females there is a proportional increase till puberty, when it is suddenly arrested, the quantity remaining stationary so long as menstruation continues regular; the average quantity being about 100 grains of carbon per hour. When menstruation ceases, it undergoes a decided increase up to the age of fifty, after which it diminishes, as in men. Should any interruption to the catamenia occur, as in pregnancy and lactation, immediately there is the same increase in the exhalation.

The whole quantity of air which passes through the lungs in twenty-four hours, is estimated at about 266 cubic feet; on comparing this with the amount of carbonic acid excreted under similar circumstances, we find the proportion of the latter to average about *four* per cent. of the whole. This proportion however may rise much higher, in consequence of a laborious respiration. Again, it may be reduced materially by the presence of a certain amount of carbonic acid already existing in the air which is respired. Hence the importance of free ventilation to ensure a proper aeration of the blood; the presence of a very small amount of carbonic acid in the air being sufficient to prevent the excretion of the due amount of it from the lungs. An animal may be kept alive in a limited quantity of air until nearly all its oxygen is consumed, provided means be taken to remove the carbonic acid, as fast as it is generated.

The nitrogen of the air is but slightly affected in

respiration. It is constantly absorbed, and constantly given out again. In animals, Dr. Edwards found that rather more was given out than was absorbed, during the summer months; but that in winter, the reverse took place.

As regards the changes produced in the blood by respiration, we have already seen that the proportions of oxygen and carbonic acid differ very much in arterial and venous blood. The results of Magnus' experiments give us the following summary:—

	Arterial Blood.	Venous Blood.
Oxygen,	23.2	15.3
Carbonic acid,	62.3	71.6
Nitrogen,	14.5	13.1

It has moreover been found, that it is in the red corpuscles that these differences chiefly are seen; hence the idea that they are to be regarded as carriers of oxygen *into* the system, and of carbonic acid *out* of it; whether or not we adopt Liebig's theory, that they possess this power by virtue of the *iron* which they contain.

As regards the cause of the *change of colour* in the blood under the influence of respiration, nothing absolute can be stated; though there are many well-established facts. The arterial hue may be produced in venous blood, by the replacement of carbonic acid by oxygen: the mere abstraction of carbonic acid will not effect it; it requires the exposure to oxygen, or the presence of saline matter. Indeed, Dr. Stevens found that unless there was saline matter present, even oxygen failed to restore the colour;—

hence the importance of saline matter to the blood, to ensure its due oxygenation.

Scherer, Mulder and Nasse adopt the view that the difference between the arterial and nervous colour is due to *physical* rather than to chemical principles; and they suppose it to depend upon a change in the form of the corpuscles;—that whenever they assume the bi-concave form they will reflect more light, and appear bright red; while in the bi-convex form, they appear dark. These changes in the form of the corpuscles are attributed to the carbonic acid, the saline matter, and chiefly, according to Mulder, to the oxy-protein produced in respiration, which is supposed to form a coating for each of the corpuscles, and by its contraction to occasion the bi-concave shape. Henle and Schultz have shown that oxygen produces the bi-concave form, and carbonic acid the bi-convex form.

The blood also parts with a considerable quantity of water, in the lungs, in the form of vapour. This is apt to be impregnated with some animal matters, and with volatile or odorous substances taken into the blood. No doubt a great part of this water is an exhalation from the extended surfaces of the pulmonary capillaries, through their very delicate membrane; but it is also likely that part of it is formed by the direct union of some of the oxygen absorbed, with the hydrogen of the oily matters of the blood. The total quantity of water thus thrown off will vary, (though not so much as the cutaneous transpiration,) with the hygrometric state of the

atmosphere: it has been estimated at from 16 to 20 ounces in twenty-four hours.

The aeration of the blood may take place, not only by means of the lungs, but also through the skin. This is particularly well seen in the skin of the Batrachia, which is soft and moist. Experiments made on the human subject also prove the same fact; for if a limb be immersed for some hours in an air-tight vessel containing pure atmospheric air, a sensible quantity of carbonic acid will be observed, which must have escaped through the skin.

Sect. 5. *Of Asphyxia.*

Before dismissing the subject of Respiration, it may be proper to note the more prominent points connected with *Asphyxia*. By this term is understood the state of system produced by a suspension of the aerating process. It may be produced in aquatic as well as in air-breathing animals, simply by cutting off the supply of air. Thus a fish placed in water from which the air has been expelled by boiling, will die as certainly as an animal placed in a vacuum.

There are many causes which may produce deficiency in the aeration of the blood; as 1, mechanical obstruction to the entrance of air, as seen in hanging, strangling, drowning, choking, or closure of the glottis by œdema;—2, a want of mechanical power, preventing due movement of the chest, as in violent compression;—3, a want of oxygen in the air, or the presence of noxious gases in it, as carbonic acid, sulphuretted hydrogen, &c.;—4, a want of nerve

power either in the respiratory ganglion, or failure in the nerves to transmit this power.

The first effect of the non-arterialization of the blood from any of the above cases, is a stagnation in the capillaries of the lungs. This is due, not to a loss of the contractile force of the heart, for as yet the heart has not been affected, but to the loss of the capillary power, resulting from a want of those chemical changes in them, which are produced in a healthy condition.

The circulation in the pulmonary capillaries is not at first entirely arrested; for the quantity of oxygen already in the lungs partially arterializes the blood, which, in this imperfect condition, is transmitted through the system, and fails to exert its due stimulus especially upon the muscular and nervous tissues. As the air in the lungs continues gradually to grow more deteriorated, the stagnation in the pulmonary capillaries becomes more complete, until finally it is entirely arrested, and the venous blood is backed up in the pulmonary artery, in the right cavities of the heart, and in the whole venous system. The arteries, on the other hand, are almost completely emptied, through the systemic capillaries not receiving new supplies from the heart.

The nervous and muscular systems lose their sensibility from two causes: the deficiency of arterial blood, and the venous character of the blood which the arteries may contain. Hence result the irregular movements, and at last an entire cessation of motion, except in the heart, which is the last to

stop,—the right side, owing to over distention, which produces a sort of paralysis;—the left, from a mere want of its ordinary stimulus—arterial blood.

The time at which asphyxia comes on varies, as before stated, in different animals, and even in different states of the same animal. In the majority of warm-blooded animals, insensibility and a loss of voluntary power come on generally within two minutes after the air has been cut off,—though the convulsive struggles may continue some minutes longer. The circulation ceases usually within ten minutes. There are certain animals, as the whale, whose vessels are arranged in large plexuses, by which the proper amount of aeration is maintained without the necessity of very frequent renewal.

In the hybernating animal the system is reduced to the condition of the cold-blooded animals, which are able to bear a long suspension of the aerating process. The same thing is true also of a person in syncope, where the activity of the functions is already reduced by a failure of the heart's power, and the demand for the respiratory process is, consequently, less. It is probable for this reason, that instances are met with of persons asphyxiated from drowning, who are restored after upwards of a half hour's submersion,—a state of syncope having been brought on at the moment of immersion, either through alarm, or concussion of the brain.

The leading indication in the treatment of asphyxia, is to restore the capillary circulation by the admission of pure air into the lungs. Artificial

respiration will often sustain life, provided the action of the heart has not entirely ceased.

Various diseases result from a defective respiration, even where life continues. One of these is the *fatty liver*, in which the fatty matter, which ought to be thrown off by respiration in the form of carbonic acid, is thrown upon this organ, distending its cells. So also, a deficiency of fibrin, resulting from an imperfect elaboration from the want of oxygen may be produced: and hence *Scrofula* is so frequently connected with unusual smallness of the chest. Again, we have various venous congestions, as of the face, the liver, the spleen, &c.:—thus, also the livid colour of the surface in apoplexy, or narcotic poisoning;—also, in typhoid fever, where the cause seems to reside in the nerve centres of respiration.

CHAPTER X.

OF SECRETION.

Sect. 1. *Nature and Conditions of the Function.*

The term Secretion literally signifies *separation*, which in fact is nearly its physiological meaning. Its essential character is identical with that of Nutrition, as each is merely a process of cell growth. The cells which are concerned in the secreting process are arranged so as to have free communication with the external surface. Thus we observe that while the cells of nutrition separate certain materials from

the blood, to deposite them in the various tissues of the body, the cells of secretion separate matters which are designed either to be thrown out of the system altogether,—as the urine; or to subserve some future purpose in the economy,—as the bile and gastric juice. The term *excretions* is generally given to the former products—and the term *secretion* retained for the latter. The excretions are made up from the decay and decomposition of the several parts of the system: they must be separated from the blood as fast as poured into it, or else they act as poisons to it, as in the case of urea or biliary matter.

The other class (true secretions) vary but little in composition from the materials of the blood; they are separated, not so much to maintain the purity of the blood, as to supply some future want of the system; for example, the suspension of the secretion of gastric juice interferes only with the function of digestion, but does not poison the blood.

The secretion of Milk differs from other secretions, in not being designed for use in the economy of the individual, but to afford nutriment to a separate being.

Although the *essential* instruments of secretion are merely cells, yet we usually find special organs set apart for the function, denominated *glands*.

A gland is nothing more than a collection of follicles closely packed together for the sake of economy of space. The follicles contain the true secreting cells in their cavities: any one of them may be regarded as an epitome of the whole gland. The

secreting cells draw their materials from the surrounding capillary rete by *endosmose.*

The character of the secretion is not at all influenced by the *form* of the gland. As a proof of this, every variety of structure for the secretion of bile and urine, is found in the different grades of animals,—from the simplest follicle, to the most complete gland: in every case, however, the ultimate cell, (the true secreting organ,) is the same.

We are ignorant of the reason why one set of cells should separate urine, another set, bile, &c.; it is a *law* impressed upon their nature, and must be received as an "ultimate fact" of science.

Difference in structure of Glands. The simplest form is where there are a number of follicles, each having a separate orifice—as the gastric follicles of the stomach; they never attain a higher development, except by a sort of doubling upon themselves: this is the condition of the most complex glands in their early stage of development,—as the liver, pancreas, &c. A higher form of gland is where a cluster of ultimate follicles open into a common duct; such are the *lobulated* glands, each lobule having its own duct—as the mammary gland. The highest form of gland is where all the ducts unite to form a single canal, as the liver, pancreas and parotid.

The *act of secretion* consists in the cells absorbing from the blood their proper materials, then swelling up, bursting, and discharging their contents into the excretory duct.

SECT. 2. *The Liver—Secretion of Bile.*

Of all glands, the Liver is most rarely absent in animals, though exceedingly variable in structure. Its development is always in the inverse ratio of that of the respiratory apparatus,—hence it is very large in the mollusca and crustacea, but in insects it is much smaller, and of a more simple type.

Minute Anatomy of the Liver. In the higher vertebra, the liver is made up of a great number of minute lobules, about the size of a millet seed. Each lobule contains all the component elements of the entire organ, as branches of the hepatic artery, of the hepatic vein, of the vena portæ, of the hepatic ducts, and the secreting cells. The lobules are connected together by areolar tissue and anastomoses of the blood-vessels. The hepatic arterial branches are distributed upon the walls of the hepatic ducts, and form the vasa vasorum of the hepatic and portal veins. They supply the nutrition of the liver. The vena portæ is formed from the collection of the veins of the chylopoietic viscera; then it subdivides like an artery, its branches proceeding to the external surface of the lobules; they are named the *inter-lobular plexus.* The vena portæ furnishes the chief materials for the *bile.* The hepatic vein commences in the centre of each lobule,(hence called *intra-lobular plexus,*) anastomoses with the inter-lobular plexus, and thus carries off the blood from the vena portæ. The ultimate ramifications of the hepatic artery are believed to discharge into capillaries of the vena portæ; hence its blood, after having become venous, contributes to form the bile. (Kiernan.)

The hepatic ducts form a plexus around the lobules,—their relation to the true *cells* of the liver is not exactly known. The parenchyma of the liver is composed nearly entirely of cells. The liver-cells are flattened and spheroidal;—they are arranged in piles, each containing a nucleus, and are filled with bilious matter and fat globules;—their *diameter* is from 1-1500th, to 1-2000th of an inch. The precise mode in which bile is separated by these cells and discharged into the hepatic ducts, is uncertain.

The progress of the bile is either directly into the intestine, or it regurgitates through the cystic duct into the gall bladder, which is its reservoir. It is probable that it is always being secreted,—but its flow into the intestine is determined by the process of digestion; hence, when death occurs from starvation, the gall bladder is found turgid. In the gall bladder, the bile undergoes concentration by evaporation of its watery particles; and it is mixed also with mucus.

Analysis of Bile.—Its solid matter is estimated at 8 to 10 per cent.; of this, about one-tenth consists of earthy salts, the remaining nine-tenths being composed of organic matter, which is remarkable for containing a very large amount of carbon and hydrogen, with a small quantity of oxygen and nitrogen. (C^{48} H^{42} O^{15} N.)

This organic matter consists chiefly of a fat acid (*bilic acid, picromel, bilin, &c.*) united with soda, to form a sort of soap, and a small portion of *cho-*

lesterin, or crystalline matter resembling spermaceti. The colouring matter, named biliverdin, is distinct from the others.

Destination of the Bile.—Much of it is excrementitious, passing off with the feces;—this portion includes the colouring matter. The soapy portion (fat acid,) acts upon the chyme in the duodenum, rendering the fatty matters of the food soluble, and thereby facilitating its absorption by the lacteals. The fatty matter of the bile is absorbed at the same time. The use of bile in digestion is shown by an experiment of Schwann: on tying the gall-duct, the animals gradually emaciated and died, in consequence of respiration not being maintained from want of *oily* materials in the system to furnish carbon.

The great design of the liver is to remove from the system the excess of hydro-carbon, which is introduced into the blood chiefly in the non-azotized food. Hence, if more of such food is taken than can be consumed in respiration, or deposited as fat, the office of removing it must devolve upon the liver; if there is too much for this organ, the injurious materials accumulate in the blood, constituting *bilious* diseases. This is especially apt to occur in warm climates, both on account of the nature of the food, and the diminished respiratory action. The remedy is exercise and an avoidance of excess in eating.

The liver is far larger in the fœtus than in the child after birth. In the former state, it is the only decarbonizing agent,—as the lungs do not act.

Sect. 3. *The Kidneys.—Secretion of Urine.*

The Kidneys are purely organs of *excretion;*—their secretion being of no further use in the economy. They exist in the lowest order of animals, but only as rudimentary organs. They begin to assume importance in fishes, and in the higher reptiles begin to be distinguished by a cortical and medullary substance;—they are lobulated in birds.

Anatomical Structure.—The kidney is divided into two well marked portions, the cortical or vascular, and the medullary. In the former, the *tubuli uriniferi* are very convoluted, and closely interlaced with blood-vessels; in the latter the tubes are straight, decrease in number, and converge towards the pelvis of the kidney. The *secretion of urine* takes place solely in the cortical portion, and is effected by the epithelium cells lining the tubuli uriniferi, from the vascular plexus on the exterior of the tubuli;—they absorb by endosmose, swell up, burst, and discharge into the tubuli.

The *Malpighian Bodies* are small dots seen on the cortical portion when cut: examined by the microscope, they are found to consist of little tufts or vessels. Each of these bodies is supplied by a branch of the renal artery called *afferent,*—which, after forming the plexus, emerges as a single *efferent* trunk, and discharges into the capillary plexus. The solid matter of the urine is secreted by the cells from the capillary plexus, but the Malpighian bo-

dies serve as a strainer, to allow the watery parts to filter through directly into the tubuli. The object of this arrangement is to provide for the constant escape of the watery part of the urine, since this constantly varies, and bears no definite proportion to the solid matter, which is governed by the previous waste of the tissues. Hence the object of the kidneys is two-fold:—to remove from the blood certain solid effete matter, and at the same time to act as a regulating valve, by which the proper amount of water is kept in the system. The amount of water discharged by the kidneys is dependent upon the action of the skin,—the one antagonizing the other.

The quantity of urine excreted by a healthy adult drinking the usual amount, in twenty-four hours, is 30 to 40 ounces. The average specific gravity is 1020. The quantity is less in summer, and the specific gravity is consequently greater: this is owing to the increase of *perspiration*. The quantity of *solid* matter in health, varies from 3.6, to 6.7 per cent.; but it is greater in disease: of this about one-third consists of alkaline and earthy salts, some of which are the same as those of the blood, but others, different. The remaining two-thirds consist of organic matters, the most important of which is *urea*: urea is soluble, and identical in composition with cyanate of ammonia. ($C^2 H^4 N^2 O^2$.)—Compared with protein, it differs in composition, in containing far more nitrogen and far less hydrogen and carbon. The object of this excretion would seem to be to carry off from the blood the *azotized* products of the disinte-

gration of the tissues, and any excess of azotized nutriment: hence, the quantity of urea is, to a certain extent, an index of the waste of the system. The average quantity of urea is about 30 parts in 1000 of urine: the amount voided daily by adult males is 430 grains;—by females 300 grains;—by children eight years old, one half that of adults;—by old men only one-third that of adults,—a fact which corresponds with the rapidity of interstitial change at these different periods of life. The amount of urea is very much influenced by exercise and diet: violent exercise always increases it, from the more rapid waste of the tissues; an exclusively animal diet increases it to 53 parts in 1000, by introducing more azotized matter into the system;—an exclusive non-azotized diet reduces it to 15 parts in 1000.

Uric (or *lithic*) *acid* is another organic constituent of urine:—only one part exists in a thousand of urine, but in the lower vertebrata, it constitutes a large portion of the *solid* matter. It is crystalline and insoluble. In human urine it is united with soda, forming a soluble compound; the *soda* is derived from the bibasic phosphate of soda. (Liebig.) Any excess of uric acid, or the presence of any other acid, causes its precipitation in the urine.

The amount of uric acid is not dependent upon the *waste* of the tissues, or upon diet; but is much influenced by certain diseases, as *gout;* hence the frequency of gravel in this affection. It occasionally is deposited directly from the blood, this disease, about the joints, forming "chalk stones."

Another constituent of urine is Hippuric acid. It was formerly supposed to be restricted to the urine of herbivorous animals. It differs from uric acid in being much more soluble, &c. It is produced in excess in human urine, by the use of benzoic acid, and at the expense of the uric acid: hence benzoic acid is deemed useful in the *lithic acid diathesis*. (Prout.)

Lactic acid is also generally considered one of the organic constituents of urine—but this is denied by Liebig. Prout considers the presence of lactic acid to be the chief cause of the precipitation of uric acid, particularly when connected with indigestion. The *saline matter* of the urine consists chiefly of sulphates of soda and potash, muriates of soda and ammonia, and phosphates of soda and ammonia. The excess of the phosphates is believed to be due to the waste of the *nervous* tissue. As before mentioned, there is a correspondence between the presence of phosphatic deposites in the urine, and excessive mental labour. The treatment of urinary deposites should be based upon a proper knowledge of the constituents of the urine. The consequence of a total *suppression* of urine is death,—chiefly from accumulation of urea in the blood: even partial retention is very serious;—it operates chiefly upon the brain and nervous system, exerting a depressing poisonous influence upon them.

SECT. 4. *Of the Mammary Glands.—Secretion of Milk.*

These organs are peculiar to *mammalia.* Their development may be detected at an early period of fœtal existence. No striking difference exists in the glands of the two sexes, till about puberty. In the female they attain their full size, previous to lactation, about the age of twenty. During pregnancy they become more vascular, and at parturition their lobulated character is distinguished; but the milk-follicles cannot be injected till full lactation. The *areola* is much developed during pregnancy.

The mammary gland of the male is a miniature representation of that of the female. It does not undergo development, except under very rare circumstances.

Minute Anatomy.—The mammary gland consists of a number of glandulæ or lobules, held together by areolar and fibrous tissue. The lobules are composed of a number of minute follicles, from which excretory ducts arise; these converge, and unite so as to form ten or twelve lactiferous tubes, which open about the centre of the nipple. At the base of the nipple these tubes dilate into reservoirs intended to hold a supply of milk;—these are larger in the lower animals than in the human female. The secretion of milk occurs in the follicles, from their epithelium cells, which absorb the materials from the surrounding blood.

Composition of Milk.—Milk consists of water, containing casein, sugar, salts, and oil globules,

(*milk globules* of Donné.) The oil globules rise to the surface when the milk is allowed to remain at rest, constituting *cream*,—which also includes some of the casein, sugar, and salts. These may be mostly separated by the process of churning, which ruptures the envelopes of the oil globules, constituting *butter* from their aggregation, and *buttermilk* containing the casein, sugar, &c.: butter yet contains some casein, which can be separated by a temperature of 180°. After removal of the cream, the milk still contains most of the casein and sugar; spontaneous change occurs in this, by conversion of the sugar into lactic acid, which precipitates the casein in flakes: this precipitation may be occasioned at any time by an acid,—but especially by *rennet*, or the dried stomach of a calf, which is so powerful that it will coagulate the casein of 1800 times its weight of milk. The *whey*, which is thus left, contains a great portion of the sugar and saline matters, which may be separated by evaporation.

The oleaginous matter consists of *olein* and *stearin*, together with a peculiar fatty substance termed *butyrin*. To the latter the peculiar smell and taste of butter are due. It is converted by saponification, into three volatile odorous acids—the *butyric*, *caproic*, and *capric* acids.

The casein is distinguished from albumen, by not being coagulated by heat alone, and by its being precipitated by feeble organic acids, as lactic. It is retained in solution, in milk, by the presence of an alkali.

The sugar contains 12 per cent. of water, so as to exist as a *hydrate of sugar;* it is nearly identical in composition with starch; but is chiefly remarkable for its proneness to be converted into lactic acid by aid of a *ferment.* The *saline matter* of milk is nearly the same as that of the blood, but with a large proportion of the phosphates of lime and magnesia.

Milk is the only secretion which contains, to any degree, the three classes of principles required for human food—viz., the albuminous, oleaginous and saccharine. The milk of the carnivora contains no sugar.

The proportion of the several ingredients of milk is liable to variation: thus in the cow, goat, and sheep, the average amount of casein, butter and sugar, each, is about 3 to 5 per cent.; but in the ass and mare, the quantity of casein is under 2 per cent., that of butter scarcely traceable,—but the sugar amounts to nearly 9 per cent.: hence it is much disposed to ferment. Human milk abounds in saccharine and oleaginous elements, but is deficient in casein. The quantity of sugar and butter in the milk is chiefly influenced by the amount of these substances in the food,—also, by the amount of them consumed in respiration: thus, a low temperature and much exercise, by increasing respiration, eliminate much of the oily and saccharine matter, in the form of carbonic acid and water; whilst rest and warmth, by diminishing this drain, favour their passage into the milk. On the other hand, the pro-

portion of casein is increased by *exercise;* which would seem to show, that the casein was derived from the disintegration of the tissues. To illustrate this:—cattle pastured in exposed situations, as in Switzerland, where they have to use much exercise, yield but a small amount of butter, but a large proportion of cheese; but when they are stall-fed, they give a large quantity of butter, and very little cheese.

The term *colostrum* is applied to the milk first secreted after parturition: it differs from common milk, in being purgative,—a quality which is useful for removing the *meconium* from the bowels of infants. This depends upon the presence of certain large yellow granulated corpuscles, as seen by the microscope. If this condition of the milk continues too long, it proves injurious to the child.

The influence of the nervous system upon the secretion of milk, appears to be greater than in other secretions; it is seen in the effects produced upon the secretion by violent emotions and passions, as terror, grief, rage, &c.;—convulsions have been thus produced in sucking children: hence the propriety of attending to the temper and disposition of a nurse.

The quantity of milk secreted by a nurse cannot readily be ascertained, since most of it occurs at the time of suckling. Milk is rendered medicinal by absorption from the blood when medicines have been swallowed.

Sect. 5. *The Salivary Glands and Pancreas.*

The Salivary Glands consist of three pairs:—the Parotids, Sub-lingual, and Sub-maxillary. Their structure is very similar to that of mammary gland,—being composed of minute follicles containing the true secreting cells, which separate the saliva from the surrounding capillary plexus, by the usual process of cell-growth. The follicles discharge into an excretory duct.

The quantity of saliva is not constant; its *flow* takes place when most wanted, that is, during *mastication;* it occurs also in a hungry person, as an emotion. The quantity secreted in twenty-four hours is estimated at 15 to 20 ounces. As obtained from the mouth, it is mixed with mucus. If the amount of mucus be considerable, the saliva has an acid reaction; if not, the reaction is alkaline.

Composition. The solid matter amounts to one per cent.; of this the animal matter consists of osmazome, mucus and a peculiar matter called *ptyalin*, which is soluble in water, and insoluble in alcohol, but yet is not identical with albumen. Ptyalin seems to act as a *ferment*, since by it starch may be converted into sugar, and sugar into lactic acid.

The *saline constituents* of saliva are nearly the same as those of the blood; its alkaline reaction is due to the tribasic phosphate of soda. The *tartar* of the teeth is owing to the earthy phosphates of the saliva, which are held together by about twenty per

cent. of animal matter. The composition of the *salivary concretions* is similar.

The influence of the saliva in digestion is not certainly determined: it is believed to be merely an adjuvant. The alkalinity of the saliva is asserted to bear a direct proportion to the acidity of the gastric juice.

The Pancreatic secretion appears to be essentially the same as the saliva.

Sect. 6. *The Lachrymal Gland.—The Tears.*

Its composition is very similar to that of the parotid, consisting of lobules, whose ultimate structure is of follicles lined by *cells*. The *Tears* very much resemble the serum of the blood deprived of its albumen; their action is slightly alkaline. They are useful to lubricate the eyes,—the excess being absorbed into the nasal duct, chiefly by capillary attraction.

This secretion is very much influenced by the emotions and passions, through the nervous system.

Sect. 7. *The Testis.—Spermatic Fluid.*

The anatomical structure of the Testis resembles that of the kidney. It is composed of a number of lobules, each containing a mass of *tubuli seminiferi*, through which the blood-vessels are distributed. The lobules vary in size—some containing more tubuli than others. The convolutions of the tubuli are so arranged that the lobules form a cone whose

apex is presented towards the rete testis. The diameter of the tubuli is very uniform,—from the 1-195th to 1-170th of an inch. The tubuli cease to be convoluted before entering the rete testis, where they are named *vasa recta.* The Rete Testis consists of from seven to thirteen vessels running in a waving direction; they then become *vasa efferentia,* and go to form the *globus major* of the *epididymis.* The Epididymis is a very convoluted canal about twenty-one feet in length;—its lower extremity is named *globus minor,* and terminates in the excretory duct, or *vas deferens.*

The original formation of the testes, in the embryo, is from the *Corpora Wolffiana*—alongside of the kidneys. In the human embryo, they first appear about the seventh week. They begin to descend about the middle period of gestation; and usually reach the scrotum at the ninth month.

The *Spérmatic Fluid* is thick and tenacious, of a grayish yellow colour. It is difficult precisely to determine its character, on account of its being mixed with the secretion of the prostate gland, and of the mucous lining of the vesiculæ seminales and spermatic ducts, before it is emitted.—It has an alkaline reaction;—it contains albumen and a peculiar animal principle named *spermatin;* likewise some salts, chiefly muriates and phosphates. The *distinctive* character of the semen is due to numerous small bodies found in it alone, and denominated *spermatozoa.* These will be more fully spoken of under the head of Reproduction.

SECT. 8. *The Cutaneous and Intestinal Glandulæ.*

The Skin is the seat of two secretions: the one—the *perspiration*, being accomplished by the sudoriparous glands,—the other by the sebaceous glands.

The *Sudoriparous* or *Sweat glands*, consist of the convolutions of a single tube—situated just beneath the cutis: this continues to the surface as the excretory duct, running in a spiral direction and perforating the epidermis in an oblique or valve-like manner. These glandulæ are exceedingly abundant over the whole body; Mr. E. Wilson says there are three thousand five hundred and twenty-eight of them on a single square inch of surface;—he has calculated the *whole length* of the perspiratory tube on the surface of a man of ordinary stature, to be 48,611 yards—or nearly twenty-eight miles.

The perspiration is divided into insensible, and sensible, or *sweat*. The former is the more usual; the latter is occasional, and is caused by excessive action of the glandulæ, or by excess of moisture in the atmosphere, preventing the evaporation from the surface. It is difficult to procure it for analysis, free from the sebaceous and other matters. It usually has an *acid* reaction, due to lactic acid, to which the same smell is owing.—The proportion of solid matter varies from one half, to one and a half per cent., consisting chiefly of an animal matter, along with some saline matters derived from the serum of the blood.

The amount of fluid exhaled from the skin, is dependent upon the surrounding temperature; being greater when it is high, and less when it is low, always provided the air be dry. The object of the increase of perspiration when the external heat is great, is to keep down the temperature by the *evaporation;* but as this cannot take place, if the atmosphere be already loaded with moisture, a hot moist air proves fatal to life. The cause of the increased secretion is due to the increased quantity of blood sent to the surface under the stimulus of heat. The entire loss of fluid by exhalation, from both the *lungs and skin,* in twenty-four hours, varies from one and two-thirds, to five pounds. Of this quantity, more than two-thirds are due to the cutaneous exhalation. The secretion of the kidney is vicarious with the exhalation from the skin and lungs, both as to the fluid and solid materials. The amount of solid matters daily thrown off by the skin, amounts to about one hundred grains. Hence the importance of a due attention to the function of the skin in urinary diseases, as well as others. When the exhalent action of the skin is completely checked, as by the application of an impermeable varnish, the effect is to lower the temperature of the body, from imperfect aeration of the blood, and ultimately to cause death: a partial suppression will cause fever, and albuminaria, or escape of the albumen of the blood into the urinary tubes, in consequence of the increased amount of albumen then sent to the kidneys. Hence, we can understand how certain cutaneous

diseases, which affect the whole surface at once, will cause intense febrile symptoms, and sometimes *albuminaria*—as seen in scarlatina. The perspiration is also greatly influenced by the nervous system; thus it is increased by the depressing emotions —as grief, fear, &c.; but diminished by high nervous excitement.

Nature seems at times to make use of this emunctory to rid the system of some morbific matter, as seen in the critical perspirations occurring in fevers, and in the acid sweats of some forms of rheumatism.

The *Sebaceous Glands* are also found scattered over the skin,—most abundantly about the face and scalp. They differ greatly in size and complexity, some being simple follicles lined by secreting cells, whilst others are more convoluted, and others again, in certain parts of the body, have a *special* function—as the *Meibomian glands* of the eyelids, and the *cerumenous glands* of the ear, which secrete the ear-wax. In the hairy part of the skin, a pair of sebaceous follicles is usually found opening into the passage through which the hair ascends. It is probable that the *odoriferous glands* are of the same nature: they are especially abundant in certain animals, and in certain races and individuals of mankind.

The Sebaceous matter is useful to lubricate the skin, and protect it from the sun and air; it is much more abundant in those living in warm climates.

The Sebaceous glands are sometimes the seat of a

certain parasite resembling a worm. It is not certain how far the Sebaceous secretion is designed to eliminate noxious matters from the blood.

The mucous surface of the alimentary canal, like the skin, is furnished with a great number of glandulæ, varying from a single follicle, to a lobulated mass with an excretory duct.

The function of the simple crypts and follicles is to secrete the protective mucus for the surface of the lining membrane.

The *Gastric follicles* of the stomach are arranged in the form of tubes, closely packed together, opening into the bottom of small depressions, or pits, which are more or less circular, their diameter being from 1-100th to 1-250th of an inch. The number of follicles opening into each pit varies from three to five. The function of these follicles is to secrete the gastric juice.

The *follicles of Lieberkühn* are little inflexions of the mucous membrane of the small intestines, whose office is the secretion of mucus.

The intestinal follicles become more prolonged in the large intestines, constituting a peculiar layer between the mucous and muscular coats;—their *function* is to secrete the thick tenacious mucus of the part. All these follicles become more evident when the membrane is inflamed;—they then secrete a whitish matter.

Other glandulæ are contained in the intestines, called Brunner's and Peyer's glands.

Brunner's Glands are found in the duodenum,

in the submucous coat. Though only the size of a hemp-seed, they consist of a vast number of follicles, united around a common excretory duct, resembling in structure the salivary glands. *Peyer's glands* are either solitary or in clusters; the latter form large patches, which are made up of aggregations of the former. Each solitary gland of Peyer consists of a closed vesicle, surrounded by a circle of openings, like Lieberkühn's follicles. Its secretion is discharged directly into the intestine, by a sort of rupture of the vesicle. The membrane which covers the cavity of the glands is very thin, and liable to be destroyed in typhoid fever by ulceration, caused, as is believed, by the deposite there of a peculiar matter, called *typhus matter.*

The function of the glands of Brunner and Peyer, is not perfectly known, but there is strong reason for the belief, that it is purely one of *excretion*—to eliminate putrescent matters from the blood, whether resulting from the normal waste of the system, or from morbific causes. No doubt, much of the fecal matter is derived from these glands, for we see it discharged from the bowels when no food whatever has been taken. Hence, the value, often, of a critical diarrhœa to rid the system of morbific matter. The colliquative diarrhœa coming on at the close of exhausting diseases, and the usual precursor of death, is probably due to the general disintegration of the solids of the body, the decomposing matter of which finds its way into the bowels, by exciting these glands to great activity. We

should be careful to avoid exciting the irritable mucous membrane, in typhoid fever, by purgatives.

Sect. 9. *Of the Spleen, and other similar Glandular Bodies.*

Although these bodies are not, strictly speaking, to be regarded as true glands, since they possess no excretory duct, still, the present place appears to be as suitable as any other, for their consideration.

The *Spleen* is an organ of compound structure, and has probably two distinct offices to fulfil. It consists of a fibrous envelope, which sends prolongations into the interior, so as to divide it into a great number of minute cavities or cells, which are termed the *Splenic follicles.* These follicles communicate freely with each other, and with the splenic vein. The interstices between the follicles are made up of the *parenchyma* of the spleen, which consists of reticulations of blood-vessels and lymphatics, with a large quantity of minute globules or incipient cells, of about half the diameter of blood corpuscles, which lie in the meshes of the capillary net-work, and which seem to be intimately connected with the lymphatics. The *Malpighian bodies* of the spleen are a large number of bodies, about the third of a line in diameter, lying in the midst of the parenchyma. These resemble lymphatics in miniature; they contain lymph of an opaque character,—an appearance resulting from the large number of lymph-corpuscles that float in it.

The walls of the spleen-cells are very distensible, which accounts for the great size this organ will sometimes attain: thus the spleen of a sheep, which weighs four ounces, may be made to contain as much as thirty ounces of water; and by tying the portal vein of an animal whose spleen weighs only two ounces, the weight is found to increase to twenty ounces. From this latter circumstance, and from the fact that the spleen becomes very much distended in asphyxia, and in the cold stage of intermittent fever, in which the blood is driven from the surface to the internal organs, the idea is entertained that the spleen serves as a diverticulum or safety-valve to the portal system and lungs. As is well known, the spleen becomes permanently enlarged in chronic ague, constituting the "ague cake." Again, the spleen seems to act as a reservoir for the superfluous blood during digestion. Its maximum size is attained about five hours after a meal.

But there appears to be another function performed by the spleen, analogous to that of the lymphatic glands. This inference is derived from the strong resemblance between the Malpighian bodies and the lymphatic glands; and is confirmed by the fact, that extirpation of the spleen is soon followed by a great increase in the size of the neighbouring lymphatic glands. This view is also supported by the fact, that while a spleen is always found in animals possessing an absorbent system, it does not exist in those which are destitute of that system.

The Supra-Renal Capsules, resemble both the

spleen and kidneys in their general structure; and, like the former, it is supposed they may have a double function,—serving as a diverticulum to the kidneys, and participating in the general absorbent system. The Supra-Renal Capsules are particularly large in early fœtal life,—surpassing the kidneys in size, up to the tenth or twelfth week.

The *Thymus Gland* is another body of much greater importance to fœtal than to subsequent life. It resembles, in all respects, a true gland, save that it has no excretory duct. It consists of a number of follicles containing a fluid in which numerous corpuscles are found. The time of its greatest development is in the early period of extra-uterine life, and not, as has been represented, in the fœtal state. Its *function* would seem to be somehow connected with that of the absorbent glands—elaborating the nutritive material, which is conveyed away by the lymphatics. Its increase usually ceases about the age of two years; after which it appears to become converted into a mass of fat, by the development of its corpuscles into fat-cells. It has also been supposed that the thymus gland may act as a diverticulum to the lungs.

The *Thyroid Gland* resembles the Thymus in its general character, but its vesicles are distinct from each other, and do not communicate with a common reservoir. Its arteries and lymphatics are particularly large. Although proportionally larger in the fœtus, it still remains of a considerable size throughout life. From all the researches into the nature of

its *function*, this would appear to be, to serve, like the foregoing organs, a double purpose,—acting as a diverticulum from the brain, and aiding in the elaboration of nutritive matter.

CHAPTER XI.

OF ANIMAL HEAT.

As has already been shown, a certain amount of heat is one of the requisites for vital action. There is a great difference, however, among animals, as to the amount of heat most favourable for the performance of their functions, and also as to their power of generating it in themselves. The invertebrata are generally *cold-blooded*, that is, have little or no power of sustaining an independent temperature. The energy of their vital actions depends upon the temperature of the external medium; when this sinks below a certain point, they pass into a state of torpidity. The same thing is true of most fishes and reptiles, though not universally.

The classes of animals most endowed with the power of generating heat, are insects, birds, and mammalia. As regards insects, this power varies very much in their different conditions; thus, in their larva and pupa states, they may be considered cold-blooded,—their temperature rising and falling with the external medium. In their perfect state, however, which is one of great activity, their temperature is many degrees higher; and this is re-

markably increased when numbers of them are crowded together, as in a bee-hive. The temperature of birds is higher than of any other class of animals,—varying from 100° to 112°. The lowest degree is found in the aquatic species, as the gull; the highest, in those most active in flight, as the swallow. The temperature of the mammalia ranges from about 96° to 104°; that of man, from 96½° up to 102°. The variations are dependent, in part, upon the temperature of the surrounding air, but they are also influenced by the general condition of the body, as to repose or activity, the period of the day, the length of time after eating, &c.;—thus, a larger amount of caloric is generated during the day than in the night; there is also a slight increase during the digestion of a meal; and a very sensible increase by *exercise*. Disease often causes great variation of animal temperature: it is increased in those conditions where the respiration and circulation are very rapid, as in the last stages of phthisis, in hypertrophy of the heart, but particularly in scarlatina and typhus fever, in which it has attained the height of 106°; and in a case of tetanus, of 110¼°. It falls in spasmodic asthma to 82°, and in Asiatic cholera and cyanosis to 77°. The *degree of moisture* of the surrounding medium has an effect upon the temperature of the body: thus a heated atmosphere of 350° and upwards may be borne, provided it be dry, so as not to prevent evaporation from the surface of the body. Experiments on animals go to prove that the body cannot be raised more than

from 11° to 13° beyond its natural temperature, without producing death.

The *source* of animal heat is due to the organic, and not to the animal functions, since heat is evolved by vegetables, particularly from the leaves and stems, in which the most active vital changes are taking place;—but most of all during the *flowering* season: thus a thermometer placed in the midst of five spadices of the *Arum* rose from 66° to 111°, and one placed in the midst of twelve spadices, rose to 121°. The same rise of temperature is seen in the *germination* of seeds, as in the process of *malting*, when the thermometer has been seen to rise to 110°. The peculiar changes which cause this elevation of temperature consist in the combination of the oxygen of the air with the carbon of the plant, so that an amount of carbonic acid is formed and set free, just as in the respiration of an animal. The reason why it is not commonly observed, is because the process is slowly performed, and concealed by a converse change,—the *fixation* of the carbon from the carbonic acid of the air, by the influence of light. It has been ascertained by careful experiment, that the amount of heat generated is in exact relation with the amount of oxygen absorbed and of carbonic acid set free; thus, if the plant be put into an atmosphere of nitrogen or hydrogen, no heat is evolved; but if it be placed in pure oxygen, the elevation of temperature is greater than usual.

The mode of the production of heat in animals is

precisely similar. We find in all warm-blooded animals provision made for exposing the blood to the influence of the oxygen of the air, and also a constant proportion between the amount of oxygen consumed, of carbonic acid generated and of *heat* evolved. The union between the carbon and oxygen must occur *throughout the system*, and not in the lungs, as has been maintained. The precise *mode* of the combination is not well understood, but it is supposed to be a sort of combustion. It appears, however, that the whole quantity of caloric generated in a given time, is greater than could be evolved by the combustion of the carbon of the carbonic acid given out during the same time: hence, there must be *other* chemical changes going on; one of these may be the union of some hydrogen with the excess of oxygen to form watery vapour;—another source is, probably, from the union of oxygen with the sulphur and phosphorus of the food;—also, perhaps, from the production of urea from the protein compounds.

From experiments on animals, it is ascertained that the *skin* performs an important part in the aeration of the blood, and the maintenance of animal heat. If the skin be entirely coated over with a varnish, the temperature is remarkably lowered, and the animal dies.

The power of maintaining animal heat is much less in young animals than in the adult; the same is true of man—the human infant being more dependent in this, as in other respects, than any other

animal. It has been ascertained, that during the first month of infant life the mortality in *winter* is nearly double that of *summer;* and the difference is attributable to the inability, at that age, to resist the effects of cold. As age advances, this disproportion decreases, till it nearly ceases at adult life; but it again appears in declining age; and at ninety years, the average mortality of winter is much more than double that of summer.

The animal temperature is very much reduced in animals *starved* to death, because there is no longer a supply of *fuel* for combustion: in fact, the reduction of the temperature is the immediate cause of death, in such cases.

CHAPTER XII.

OF REPRODUCTION.

SECT. 1. *Nature and Objects of the Function.*

The function of Reproduction is essentially the same as that of Nutrition: the only difference is, that while in the former, the newly formed parts are destined to be cast off from the parent structure and to become a new being, in the latter, they are designed to constitute a part of the original whole. The identity of the two is seen in the simplest Cryptogamia, as the *yeast fungus,* where every single cell is a new being, and where the process of nutrition is, at the same time, that of reproduction. The same thing is seen in the lowest animals, as the Polypi.

In the simplest cellular plants, the production of a new being takes place by a rupture of the parent-cell, and the emission of its contained molecules, each of which is capable of undergoing the same process for itself. So, in the lower order of animals, many are reproduced by a process similar to the *budding* of plants: it is but a modification of the process of nutrition, by which, also, lost parts are restored.

In the higher plants and animals there are not only *germ-preparing* cells, but, likewise, *germ-nourishing* organs,—the ovules or ova, in which the former may be developed. In the vegetable, these two sets of organs are very often united in one individual,—the same flower furnishing the pollen and the ovule. In some animals, as the mollusca, the same union of organs occurs; the two sets of organs may be present in each individual, and yet coition be necessary for mutual impregnation; or finally, the sexes may be entirely distinct,—one individual possessing only the *male* or germ-producing organs, the other, the *female* or germ-nourishing apparatus.

SECT. 2. *Action of the Male.*

The reproductive action of the male, consists in the formation and liberation of the reproductive germs. These are prepared within the peculiar cells of the tubuli seminiferi of the testis, and named *Spermatozoa*. They are found in no other

secretion, and in the testis only when the animal is capable of procreation. They may consequently be considered as an instance of the highest power of cell-action, and they afford an illustration of what Schwann calls the *metabolic* force of cells.

The human spermatozoon consists of a little oval flattened body, from the 1-600th, to 1-800th of a line in length, from which proceeds a long tapering tail about the 1-50th of a line in length,—the whole transparent. It is distinguished by its powers of spontaneous movement, which has caused it to be considered as a proper animalcule, but it is now believed to be analogous to the pollen of plants, which often exhibits the same tendency to rapid movement when separated from the parent structure. The movement is principally performed by undulations of the tail, and may continue for many hours after emission of the fluid; and it is not checked by their admixture with the urine, &c. They can be detected by the aid of the microscope, in the urine, in cases of nocturnal emission.—They are developed within the seminal cells, and arranged in bundles.

The power of procreation in the human male, is not generally found before the age of fourteen to sixteen years. This period is called *puberty*. Certain characteristic changes then occur—as development of the sexual organs, growth of hair on the chin and pubes, enlargement of the larynx producing hoarseness of voice, general enlargement of the frame, and the awakening of new feelings and

desires.—The procreative power may last, if not abused, in vigorous persons to the age of sixty to seventy years, or even longer.—The secretion of semen is very much under the influence of the nervous system—Its *excessive* formation appears to be a tax upon both the mental and bodily powers; it is a law, both of vegetables and animals, that the development of the individual or the reproduction of the species, are in an inverse ratio to one another.

The emission of semen is purely a *reflex* act,—being entirely independent of the will. Under the stimulus of the venereal excitement, an impression is produced upon the spinal cord, which causes a reflex contraction of the muscles surrounding the vesiculæ seminales,—these receptacles discharge their contents into the urethra, and from this they are expelled by the compressor muscles. *Sensation* is not absolutely essential to the act, for the impression conveyed to the spinal cord may excite the contraction of the ejaculator muscles, like other reflex actions, without producing sensation.

Sect. 3. *Action of the Female.*

The office of the female is to receive the germ prepared by the male, and to supply it with nourishment for its future development. The process by which this is effected is essentially the same as in plants: peculiar bodies, termed *ova*, are produced in certain parts of the female structure; these contain a store of nutriment. The reproductive germ reaches

the ova, and begins to grow at the expense of the materials which they yield. This may be all that the embryo requires, save a warm temperature, to develope itself into a perfect being—as is the case in birds and reptiles, in which the development of the embryo takes place separate from the mother; or it issues from the egg in a form different from what it is permanently to assume—but still capable of supporting itself;—or a new connexion is formed between the embryo and the mother, by which the latter continues to supply the former with nutriment from its own blood, as in the mammalia and man. This is the condition of most of the invertebrata. The changes of insects from the larva up to the perfect form are to be regarded only as an embryotic development.

The condition of the *ova* varies in different animals: in the lowest, they are scattered throughout the body, just as are the seminal cells; in others, they resemble true glands; but in the bird, reptile and mammal, and in most fishes, they are only masses of parenchyma, copiously supplied with blood-vessels, and having dispersed through their substance certain peculiar cells termed *ovisacs*, within which the ova are developed. In order that the ova may be set free, not only must the ovisac itself burst, like parent-cells in general, but the peculiar tissue and the envelope of the ovarium must give way. When the ovum has thus escaped into the cavity of the abdomen, it may either remain there, to be shortly discharged by simple openings, in the

walls,—as is the case with certain fishes, or it may at once be received into the expanded extremities of tubes called *oviducts*, to convey it out of the body. In mammalia, the oviducts are named *Fallopian tubes;* but these unite and enlarge to form a *uterus*, in which the embryo is retained for further development. The uterus is peculiar to mammalia; but in many of the other animals the embryo is retained within the oviduct till it has been sufficiently developed to be born alive.

The structure of the *ovule* or unfertilized egg, is essentially the same in all animals. Neither the albumen which forms the white, nor the shell with its membrane, exist in the ovum until after it has left the ovary; and in some cases, as the lower invertebrata, they are not present at all. The *true* ovule consists of the yelk-bag and its contents—the yelk. The yelk or yolk is composed chiefly of albumen and oil globules; and it is this substance, which, like the starchy and oily matter laid up in the seed of plants, is destined to nourish the embryo till it is able to support itself, or, as in the case of mammals, form a new connexion with the parent. Floating in the yelk is a peculiar cell, termed the *germinal vesicle;* and upon its wall, a distinct nucleus, called the *germinal spot*.

In the mammalia the yelk is much smaller than in birds, because it is intended to afford nutriment only in the earliest stage of the embryo.

The capsule or investment of the ovum is termed the *Graafian follicle*, the inner layer of which is

the proper ovisac. The ovisac and ovule are not in immediate contact: between them we have a layer of cells surrounding the ovule, termed *tunica granulosa;* another layer lines the ovisac, and is called *membrana granulosa.* These two membranous expansions are connected together by four band-like extensions, named *retinacula:* they appear to suspend the ovum in its place.

Ova are seen in the ovarium of the fœtal animal; and during the period of childhood there is a continual rupture of ovisacs, and a discharge of ova, but these are not sufficiently developed to be fit for impregnation. Their evolution takes place much more rapidly and completely about the period of *puberty* —at which time the stroma of the ovarium is crowded with ovisacs. This same increased development of ova is seen also during the period of *heat* in animals, whose powers of conception are periodic. The period of puberty in the human female is usually between the thirteenth and sixteenth year,—earlier in warm climates than in cold, and in towns than in the country. The period is also hastened by luxurious habits, an inert life, and sensual indulgence. The changes which occur in woman at this time are chiefly connected with the reproductive organs: as development of the mammæ, increased size of the pelvis, but above all, the appearance of the catamenia.

The *menstrual* or *catamenial flow* is always an indication of the aptitude for procreation;—but, as it is often delayed, its absence is no criterion of an inability for this function. The interval between

the successive appearances of the flux, is about four weeks: the *duration* of the flow, from three to six days; but the return is apt to be more frequent, and the duration longer, in females of luxurious habits and relaxed frame. The first appearance is usually accompanied by considerable disturbance of the system. It is believed to be a true *secretion* from the lining membrane of the uterus, and appears to consist of the elements of blood in an altered condition, as there is an absence of most of the fibrin and albumen, but not of the red globules; consequently, it does not coagulate, in its normal condition. The appearance of clots is an indication of *abnormal* menstruation. The catamenia are not entirely confined to the human female; a similar secretion is observed in most of the mammalia during *heat*. The chief peculiarity in woman is its *monthly* return. Recent observations confirm the fact, that the condition of the female generative system, during menstruation, is similar to that of animals during *heat*, that is, there is then a greater tendency to conception;—also, that at this period there is usually a discharge of ova, by the rupture of the ovisacs, more frequently than at other times; but still, that menstruation may occur without any such rupture. The duration of the procreative power of the female, as marked by the catamenia, is usually till about the forty-fifth year; though, occasionally, prolonged ten or fifteen years longer. Generally, there is no menstrual flow during pregnancy or lactation,—though this is not invariably the case, particularly as regards lactation.

The function of the female during coitus is entirely passive. The secretion and discharge which occur during excitement arise from the *Glands of Duverney*, small rounded elevated bodies situated at the entrance of the vagina, on either side;—they are analogous to Cowper's glands in the males, and discharge upon the inner surface of the nymphæ. All that is necessary to ensure impregnation, is the introduction of a small quantity of the spermatic fluid just within the vagina. It is uncertain how the spermatozoa make their way to the ovum, but it is believed to be by their own inherent power of motion.

Changes in the Ovule before Fecundation.—When the ovule is nearly at maturity, it begins to move from the centre of the ovisac, where it had been suspended by the retinacula, towards its periphery, and always to that side of it which is nearest the surface of the ovary. In the mean time, the portion of the ovisac in immediate contact with the ovum thins away, and the outer portion, or the Graafian follicle—especially that part most deeply imbedded in the ovary, becomes thicker, by a deposite of fibrinous matter between this layer and the proper ovisac. This produces pressure of the ovum against the thinnest part of the vesicle, which ruptures and allows it to escape into the entrance of the Fallopian tube.

The fibrinous matter just alluded to, together, as it would seem, with the remains of the ruptured ovisac, becomes organized, and forms the *corpus luteum*. This is the history of the escape of an ovule from the ovarium, whether impregnated or unimpregnated; but the *corpus luteum* of the preg-

nant state is much more highly organized than that of the unimpregnated condition.

Changes in the Interior of the Ovum. While the ovum is moving towards the periphery of the ovisac, the yelk becomes filled with cells, which, after passing through successive generations finally disappear, leaving the fluid apparently in the same condition as before. This process of cell-development in the yelk continues for some time after fecundation; its object seems to be, to prepare the matters of the yelk for their future functions in the nutrition of the embryo. At the same time, the *germinal vesicle* is moving from the centre of the yelk to its periphery, and always to that side of it which is nearest to the ovary; and the *germinal spot* is always on that side of the vesicle which is nearest to the yelk-bag;—thus, we find the germinal spot to be very near the surface of the ovary. A successive development of cells takes place in the germinal vesicle, commencing upon the edge of the germinal spot, and sprouting forth towards the centre. These cells enlarge, and another ring of them is developed within; and so on, successive annuli of cells, one within the other, until the whole germinal vesicle is filled with minute cells, except the centre of the germinal spot, which remains pellucid. All these cells deliquesce, just like the yelk-cells previously described: their object seems to be, to prepare the contents of the germinal vesicle for the nourishment of the germ which is to be introduced into it.

By the above changes, we see how the germinal vesicle is brought very near the surface of the ovary. It is still covered, however, by the peritoneal coat of the ovary, by the Graafian follicle, by the ovisac, and the yelk-bag, which in mammalia is termed the *zona pellucida*. The three former of these, as we have noticed, gradually become thin, and rupture, allowing the ovule to escape; and about the same time, the zona pellucida divides, so as to form a chink just above the pellucid centre of the germinal spot; and it is through this fissure that the spermatozoa reach the vesicle, so as to fertilize it.

We are ignorant of the precise *influence* communicated by the spermatozoon upon the ovule; but it is believed to deposite in the germinal vesicle the *germ* of the future being, in the shape of *two cells;* —which is analogous to the fertilizing process in plants. It is not quite certain whether the process of fecundation takes place, in mammalia, before the ovule has burst the ovisac, or while it is passing along the oviduct.

Changes occurring after Fecundation. After fecundation, the germinal vesicle returns to the centre of the yelk, and a new series of changes begins to take place. The two new cells, called *twin-cells*, occupy the place of the germinal spot; they rapidly increase in size, and develop new cells in their interior. Their development is peculiar,—it is by a process of *doubling*, the original pair become four, these four become eight, and so on, until the whole mass resembles a mulberry;—this is termed the *germinal mass.*

From the germinal mass, the *germinal membrane* is formed, by the sending off layers of cells, in the form of a membrane, which pass round the yelk, so as completely to enclose it, but being within the zona pellucida or yelk-bag. The germinal membrane, in the higher animals, consists of three layers;—the external one, which is formed first, is named the *serous;* the internal layer is formed next, and called the *mucous;* and the intermediate one is formed last, and called *vascular.*

Thus we have the first development of the embryo into a *sac* enclosing a store of nourishment: it is, in fact, a stomach enclosing its own aliment; for it is by means of the mucous layer of the germinal membrane, that the nutritious material is appropriated to the support of the embryo. In the lowest animals, as the Polypi, the process of embryotic development does not proceed much farther than this point; for the external layer of the germinal membrane becomes the *integument*, the internal layer the *stomach*, and the space occupied by the yelk, the *digestive cavity.* But in the higher animals, the greater part of the germinal membrane is destined to be thrown off as useless;—for a single large cell seen in the midst of the "mulberry mass," is in reality the origin of nearly the whole of the permanent structure of the embryo. This single cell, termed the Embryonic Cell, along with a cluster of surrounding cells, reaches the surface of the yelk, and constitutes the *cicatricula* or *tread*, in the impregnated egg. The transparent space in its

centre, is named *Area pellucida*, and the faint line seen in the centre of this, the *Primitive trace.* The same evolution of the embryonic cell then takes place that happened to the germinal vesicle, namely, the development of successive annuli of cells,—the outer ring of which assumes the form of a membrane, and in fact, constitutes the *inner* layer of the germinal membrane.

The above changes are taking place in the ovum, while it is passing through the Fallopian tube. During this transit, the mammalian ovum receives an addition analogous to the white of the egg of birds; and this is surrounded by a fibrous layer similar to the lining membrane of the egg-shell: this envelope becomes the *Chorion.* On its surface are seen numerous villi, or processes, which give it a shaggy appearance. These processes act as absorbing radicles; and it is by this means that the embryo is nourished from the fluids of the parent, until a more perfect communication is established through the placenta.

The *Membrana Decidua* of the uterus is so named from its being cast off at each parturition. It is formed from the surface of the lining membrane, by means of epithelium cells. Its thickness is from one to three lines. It covers over the neck of the uterus and the orifices of the Fallopian tubes. It is formed when impregnation has occurred, whether the ovum has reached the uterus or not, as it is found in cases of extra-uterine pregnancy. At a later period, the decidua consists of two layers—the

decidua vera, lining the cavity of the uterus, and the *decidua reflexa*, reflected over the ovum. The decidua reflexa was formerly supposed to be a portion of the decidua vera merely pushed before the ovum, and *developed* over it: but from the difference of their structure, it has probably a different origin. These two layers gradually come in contact as the ovum grows; and the space between them is usually obliterated at the third month, so that they cannot be distinguished from each other.

Formation of the Placenta. It commences by the penetration of the villi of the chorion into the tubuli of the decidua. These villi serve as roots, to suck up and convey to the embryo the nourishment prepared by the maternal structure. This is the earliest and simplest mode by which the fœtus forms a connexion with its mother, and it is the *only* one that takes place in the lower animals, called *non-placental.* In the higher animals the tufts of the chorion form a vascular connexion with the fœtus by means of the *Allantois*,—as will presently be seen; then the vascular tufts are particularly developed at a certain spot of the chorion, where they are collected in large numbers, forming the placenta. In some of the lower tribes the maternal and fœtal portions of the placenta can be distinguished, but in the human female the elements of the two are completely intermingled throughout. The fœtal portion of the placenta consists of the subdivisions of the umbilical vessels, the ultimate ramifications of which are in the form of villi, each

containing a capillary vessel in the shape of a loop, and communicating with an artery and vein. The vessels of the placental villus are surrounded by cells enclosed in a basement membrane. The *maternal* portion of the placenta consists of a prolongation of the internal coat of the great uterine vessels, forming a sort of enlarged sac. Against this sac the placental tufts project, so as to form out of it a sheath for themselves. The blood is conveyed into the placenta by the "curling arteries,"—so named from their peculiar course: they proceed from the uterine arteries, the blood being returned through the large uterine veins called *sinuses*.

Hence, there is no *direct* communication between the blood of the mother and that of the fœtus. The fœtal tufts being bathed in the maternal blood, draw from it, by means of their cells, the proper materials for the nutrition of the embryo. They may be compared to the villi of the intestines, which dip down into the fluids of the alimentary canal, and by means of their cells, elaborate their appropriate materials. But they also perform another important function,—that of respiration, for the embryo, by giving out their carbonic acid to the maternal blood, and receiving oxygen from it: in this respect the fœtal villi resemble the gills of fishes.

The formation of the human placenta commences about the end of the second month of utero-gestation, and acquires its proper character during the third month. The vessels of the uterus become enlarged throughout, but particularly about the

attachment of the placenta; and the blood in moving through them produces a peculiar purring sound called *placental bruit*, which is heard as early as the twelfth week of pregnancy. It is synchronous with the pulse of the mother, and is a *diagnostic* sign of pregnancy.

Continuation of the development of the Embryo. The Nervous system is the first portion of the permanent structure which is seen. It is found in the nucleus of the embryonic cell, and named *Chorda dorsalis.* From this is formed, by a process of cell-development, the vertebral column.

The Vascular system begins to appear very soon after, or concurrently with, the first appearance of the nervous system. The first development is in the vascular layer of the germinal membrane, in the form of a very fine network of vessels called the *vascular area.* This gradually extends itself till the vessels spread over the whole of the membrane. The *blood disks* seem to originate from the nuclei of the cells of the vascular layer, whilst the first *vessels* are probably formed from the elongation of the cells. The vascular network serves to convey the nutritious matter of the yelk-bag to the embryo. The vessels of the yelk-bag terminate in two large trunks called *Omphalo-Mesenteric* or *Vitelline vessels*, which enter the embryo at the point that afterwards becomes the umbilicus. The first movement always takes place *towards* the embryo, and can be perceived before the heart is seen. The *Heart* is formed in the substance of the vascular layer, by a

dilatation of the trunk into which the blood-vessels unite: this, shortly after, becomes bent upon itself; then it divides into cavities,—the walls gradually acquiring strength. In this early condition, the heart is known as the *punctum saliens*.

The *Digestive* system is developed along with the vascular. It commences by a doubling in of the mucous layer, under the abdomen of the fœtus, so as to enclose a cavity; this, by subsequent prolongation and involution, is moulded into the stomach and intestines. This digestive cavity communicates for some time with the yelk-bag, from which, in a measure, it has been pinched off,—through the opening left by the imperfect closure of its walls. In the mammalia, this orifice is gradually narrowed, and at last completely closed; and the yelk-bag, thus separated, is afterwards thrown off. It is then named the *Umbilical Vesicle*, and may be detected upon the umbilical cord up to a late period of pregnancy.

Formation of the Amnion. That part of the serous lamina of the germinal membrane surrounding the *area pellucida* rises up on each side in two folds; these gradually approach each other, in the space between the embryo and the chorion, so as to form an additional investment for the former. Each of these folds contains two layers of membrane; and by gradually enlarging themselves, the *outer* layer comes at length in contact with the inner layer of the chorion, and adheres to it; while the *inner* layer remains as a distinct sac, and is called the *Amnion*.

Within it is contained the *liquor amnii*—which resembles dilute serum. The *Allantois* is a sort of process from the digestive cavity; at first it is a small vesicle, which, in birds, is subsequently prolonged so as to extend round the whole of the yelk-bag. Its *function* in the egg of birds is to aerate the fluid, through the membrane of the shell. In the ovum of the mammalia, its chief office is to convey the vessels of the embryo to the chorion, and its extent corresponds with the size of the placenta. When the attachment of the embryo to the uterine surface, by means of the placenta, has taken place, the allantois, being of no farther use, shrivels up so as scarcely to be seen. The lower part of the allantois remains as the urinary bladder, and the duct by which it was connected with the abdominal cavity, becomes the *Urachus* or suspensory ligament of the bladder.

The *Umbilical Cord* consists of:—1. The umbilical vessels, comprising two arteries and one vein. 2. The remains of the umbilical vesicle and duct. 3. The omphalo-mesenteric vessels. 4. The urachus. 5. The investment of the whole, made from a reflexion of the amnion.

The Arteries are branches of the hypogastric;—their function is to convey the blood of the fœtus to the placenta, to be revivified. The Vein returns the blood to the fœtus, and empties partly into the vena portæ, and partly through the ductus venosus into the aorta.

The *Circulation* of the fœtus is somewhat similar

in character to that of the higher reptiles; that is, the heart contains both arterial and venous blood, which is owing to the peculiar arrangement of the circulating system.

It is not quite certain upon what "Quickening" depends, though it is commonly ascribed to the first movement of the fœtus in utero.

The average *duration of pregnancy* in the human female, is 40 weeks, or 280 days: it is occasionally prolonged from one to three weeks. By the law of France, 300 days are the limits assigned for a legitimate birth. Among the lower animals such prolongations are not unusual. It is not ascertained what is the cause of the departure from the general rule, but it is probably owing to some peculiarity in the male germ;—from observations made by cattle-breeders upon cows in calf by a certain bull always exceeding their time, and some few coming short of it.

The shortest period at which gestation may terminate, consistently with the life of the child, is not determined—owing to the impossibility of exactly determining the time of conception. Although an infant is not usually considered *viable*, if born before the end of the seventh month, there are cases on record of their living, though born in the twenty-fifth or twenty-sixth week.

The act of *parturition* is accomplished partly by the contractions of the uterus, and partly by the contraction of the muscles of the abdomen. We do not know why it should occur just at one period, any more than we can account for other periodic

phenomena. The term "Labour" is applied to the expulsion of the fœtus. It is partially of a *reflex* character, as seen by the contractile effects produced by irritation made at different parts of the body.

CHAPTER XIII.

OF THE FUNCTIONS OF THE NERVOUS SYSTEM.

SECT. 1. *General Considerations.*

The composition and structure of the Nervous tissue have already been treated of, (Chap. IV., Sect. 5.) From what was there stated, it is evident that no nervous system can exist, unless the two forms of elementary nerve matter be present,—the *ganglia*, composed of vesicular substance, to originate power, and the *nerve trunks*, composed of fibrous or tubular matter, to transmit the power.

The possession of a nervous system has been generally deemed the peculiar point of distinction between *animal* and *vegetative* or organic life; since it is connected, not with the evolution of *forms*, but with the display of *forces*. Its phenomena may be comprised under the three heads of Spontaneous Movement, Sensibility, and Intelligence. These phenomena are not equally manifested in all animals, simply because the nervous system is not equally developed in them all. In the very lowest forms of animal life it is not possible to demonstrate the existence of a distinct nervous system; hence, those Physiologists, who contend for the identity of

Vitality and Nerve Life, and suppose that *none* of the acts of the living being can be performed without a nervous system, are forced to adopt the hypothesis of the existence of a "diffused" nervous system, that is, the presence of nervous particles, in a separate form, incorporated with the tissues,—as a necessary alternative to a want of indication of its existence. Such certainly overlook the fact, that even in the highest animals, all the organic, and some even of the animal functions, are performed without the necessary interference of the nervous system. Hence, it is not from the mere manifestations of *vitality* that we are led to infer the existence of a nervous system in these animals; but from their exhibiting evidences of *sensibility* and *spontaneous movement*. Such animals have been classified as the *Acrita*;—they constitute the lowest tribe of the Radiata.

The complexity of the functions of the nervous system is always proportionate to the degree of its development; thus, in the animals lowest in the scale, (in whom a nerve structure can at all be perceived,) we find merely a ganglion with a nerve attached; and the only function performed is that of spontaneous motion,—the impression being transmitted from its exterior to the ganglion, and thence by a reflex power, through the efferent fibres, exciting motion. A little higher in the scale, we have evidence of a distinct sensibility; and higher still, we find intelligence manifested, through the development of the brain.

The degree of the development of the nervous system has been made, by some naturalists, the basis of their classification. They divide the animal creation into five classes, namely, I. The Acrita, or those of a diffused nervous system. II. The Nematoneura, or those possessing a thread-like nervous system. III. The Heterogangliata, in which the nerve centres are distributed irregularly throughout the body, being placed near certain organs. IV. The Homogangliata, or those, in which the ganglia are united upon a line: they exhibit an appearance of symmetry, the half of each ganglion presiding over one-half of the body. V. The Vertebrata, or those in which the ganglia are enclosed in a bony case—*the spine.*

Our knowledge of the nervous system is derived from several sources,—as comparative anatomy and physiology, microscopic examinations, experiments—particularly vivisections, and pathological observations. The last are, generally speaking, most to be relied upon.

SECT. 2. *Comparative Structure of the Nervous System in different Animals.*

The study of the comparative anatomy of the nervous system affords us an excellent method of unravelling this apparent complex portion of the animal organism. The condition of this system in the very lowest of the Radiata (the *Acrita,*) has already been noticed. In the higher Radiata, as the *Star-Fish,* the mouth is surrounded by a filamentous

ring, which presents a regular series of ganglionic enlargements, one of them corresponding to each segment of the body, and each sending a branch to the corresponding ray, and two smaller ones to the viscera within the central disk.

In the Mollusca, which are characterized by the great predominance of the nutritive system over that of animal life, the nervous system generally bears but a small proportion to the whole mass of the body. The part that is chiefly developed is that which presides over the *special* functions; thus in the higher mollusks there are at least three ganglia:—the *bronchial* or respiratory, the *pedal* or locomotive, and the *cephalic* ganglion, which is the centre of its sensations. Frequently we find other special ganglia superadded.

The Articulata are the reverse of the Mollusca, being characterized by great muscular development and energy of movement; and in them the nervous system is almost entirely subservient to this function. It consists usually of a chain of ganglia, connected by a double cord extending from the head through the body. Each ganglion is double,—one half for each side; and one ganglion is generally appropriated to each segment of the body, which it supplies with nerves. In some cases, the number of these segments amounts to several hundred, and the number of ganglia equally increases. Each segment is a perfect representation of the others, but is entirely independent of its fellows, as may easily be shown by cutting up a centipede or earth-worm

into any number of pieces, every segment exhibiting motion when irritated, through *reflex* action. The *cephalic* ganglia are always the largest: they are connected with the organs of special sense.

From numerous observations and experiments upon the Articulata, it would appear that the ordinary movements of their legs and wings are of a reflex character, though harmonized and directed by their instinct, or will, which act through the cephalic ganglia. It also appears, that although this class of animals are chiefly remarkable for their *instinct*, (as witnessed in the bee,) still, their actions are of a *consensual*, rather than of a *rational* character.

In the Vertebrata the nervous system differs from that of the foregoing classes in two important particulars: in the latter it appears only to be an appendage to the rest of the system; in the former the whole structure seems to be subservient to it, and designed to carry out its purposes. Again, the Vertebrata possess a complete bony casing for the protection and support of the nervous system, while no such special provision exists in the Invertebrata.

In the Vertebrata, the nervous systems of both the Mollusca and Articulata appear to be united, since they combine the *sensory* powers of the one, with the *locomotive* powers of the other. But there are also parts superadded, which are not found in either of the others: these are the cerebellum and the cerebrum, which are superimposed, as it were, upon the cephalic ganglia of the others,

which are only connected with the organs of special sense.—Again, we find the different locomotive ganglia united together in one continuous cord—the *spinal marrow,* though the independence of each is still preserved. The upper portion of the spinal cord, which is prolonged into the cranium so as to be in immediate relation with the encephalon, is termed the *Medulla Oblongata,* and is the centre of the respiratory and stomato-gastric nerves. The *visceral* or *Sympathetic* system of nerves also assumes a more distinct form; but its ganglia are not, for the most part, protected, as the others, since they lie in the cavity of the trunk.

We will now proceed to give a condensed description of the structure and functions of the different parts of the Nervous System.

Sect. 3. *Functions of the Spinal Cord.*

The Spinal Cord was formerly regarded as a mere bundle of nerves proceeding from the brain, and quite subordinate to it; but it is now well ascertained to be a distinct nervous centre, and to be of far greater importance to organic life than the brain itself, since an animal can live even if deprived entirely of its brain, which it cannot do, if the spinal marrow, including the medulla oblongata, is destroyed. It is also known that the functions of the spinal cord are independent of, and often opposed to, the will; and that its actions are of a *reflex* character; that is, the motor impulses which originate in

it are not spontaneous, but are the result of impressions made on it by the afferent trunks, and without the necessary intervention of sensation.

The *adaptiveness* of reflex movements is no proof of the existence either of the consciousness or will of the being who executes them. The adaptation is made *for* the being—not *by* it; and it arises from the law impressed by the Creator upon the nervous system, by means of which, a certain movement adapted to produce a certain effect, is executed by a certain impression.

This same reflex movement occurs also when the spinal marrow is divided into segments,—each segment being a distinct centre of power; but in this case the irritation must be made upon the part supplied by the nerves of the same segment, in which alone the movement will occur. But where the spinal marrow is whole, and the brain has been removed, then an irritation made on *any* part of the surface will cause motion even in distant parts. An illustration of this is seen in convulsive movements, which are often brought on by some local irritation.

The spinal cord is bi-lateral, being composed of two distinct halves united together in the middle by commissural fibres. This union is much closer in man and mammalia, than in the lower vertebrata, but the division is still marked by a deep anterior fissure and a shallower posterior one. There are also two lateral fissures on each side: so that each half is divided into an *anterior*, *middle*, and *posterior* column. The gray or cineritious matter is on the interior, and

the medullary matter on the exterior. If a transverse section be made, the gray matter is seen in the form of two crescentric patches, the points of each crescent being directed towards the lateral fissures of each side, and the convexities approaching very near each other, and connected together by a transverse band of gray matter. The relative portions of white and gray matter vary in different parts of the cord. In the cervical region there is an increase of gray matter corresponding with the origin of the brachial plexus; there is a still greater increase of the gray matter in the lumbar region, corresponding with the origin of the nerves of the lower extremities. In many of the lower animals, the same variation is observed,—the increase of the gray matter being always well marked at those points of the spinal cord where there is a great amount of power to be supplied: thus, in the Flying-Fish, it is seen when the pectoral fins are supplied; in birds of active flight, the enlargement occurs opposite the wings; and in birds of great locomotive powers, as the ostrich, it is most evident in the posterior ganglia. Hence the inference, that the increase of the gray matter of the spinal cord is, in some way, connected with the amount of *power* to be supplied.

The roots of the spinal nerves all consist of an anterior and posterior fasciculus; and the functions are quite different. It is proved by experiment, that the *posterior* roots are made up of afferent fibres, and only convey impressions towards the nervous centres; which impressions, if confined to

the cord itself, excite *reflex* action; but if conveyed to the brain, they produce *sensations*. Again, it is equally certain that the anterior roots are made up of efferent fibres, which convey, from the nervous centres, motor power to the muscles. If the impulse comes from the cord only, the movement is entirely *reflex;* if from the brain, it is *voluntary*. On this view, then, each spinal nerve consists of *four* sets of fibres, as follows:

1. A *sensory* bundle passing upwards to the brain.

2. A set of *excitor* or *afferent* fibres conveying impressions to the spinal cord.

3. A *motor* set, conveying the influence of volition and emotion downwards, *from* the brain.

4. A *motor* or *efferent* set, conveying motor power *from* the spinal cord.

Of these, the first and second are united in the *posterior* roots; the third and fourth in the *anterior* roots.

The roots of the spinal nerves can be traced into the gray matter; and it is highly probable that many filaments also connect with the medullary portion of the cord, and are by this means united with the brain. Sir C. Bell's opinion that the functions of the *columns* of the spinal cord are similar to those of the roots of the nerves connected with them, is not fully borne out by observation on the effects of disease upon the different parts of the cord.

The particular reflex actions dependent upon the

spinal cord have chiefly reference to the *organic* functions. They are, for the most part, of an *expulsive* kind, as defecation, urination, parturition, and the ejaculatio seminis. Over the two former the will has some control, so long as the stimulus is not very violent; but not over the two latter, when once the stimulus has come into action. The movements of the lower extremities seem also, in a great measure, governed by reflex action. This is particularly seen when the influence of the brain is suspended, so as to destroy the power of the will; then the slightest stimulus, such as tickling the sole of the foot, will produce decided movements in the limb. It is very probable that much of locomotion in man is produced by reflex action, after it has once been commenced by an effort of the will. It is certain that birds can continue their flight, when deprived of their cerebrum.

The reflex action of the spinal cord is often of an abnormal or pathological character. *Convulsion* is one of the most common disorders connected with it and the medulla oblongata. Three forms of convulsive diseases are noticed:—1. They may be simply *reflex*, resulting from some unusual irritation. 2. They may be merely *centric*, that is, resulting from a peculiar condition of the spinal centres, which occasions muscular movement without stimulation. 3. They may depend upon both causes combined, —the nervous centres becoming very irritable, and susceptible to the slightest irritations, which would

commonly be harmless. This last class is the most common, as seen in the convulsions caused by teething, intestinal worms and irritable matters in the stomach and bowels;—the convulsions ceasing when the irritation is removed. Instances of the *centric* form of convulsion are afforded in hydrophobia, tetanus, epilepsy and hysteria. In hydrophobia the medulla oblongata and the ganglia of special sense are likewise involved,—their peculiar condition being the result of a virus introduced into the blood; the brain entirely escapes. When once the centres are excited, the slightest stimulus will produce the most violent spasms. The stimuli which display the most powerful influence are those which act through the senses, as sound, sight, and taste. Tetanus is a very similar affection, only the ganglia of special sense are not involved. It may originate entirely in the nerve centres, as in the idiopathic form; or it may arise from an external irritation, as a lacerated wound, constituting the *traumatic* form. The injured nerve transmits the irritation to the nervous centres and sets up an excitable state in them. Hence it is, that the removal of the original source of irritation rarely proves beneficial, because the nerve centres being now affected, the spasm will be excited by the slightest irritation. Epilepsy consists of convulsions attended with temporary suspension of the functions of the brain. It also may result from local irritation as teething, and will cease on the removal of the cause; but when confirmed, the ner-

vous centres become diseased, and no treatment appears to do good.

These diseases prove fatal by the suspension of respiration, through spasm of the respiratory muscles. Hysteria may imitate all the others; but in it there does not seem to be any fixed disease, so much as a peculiar *general* nervous excitability. It is often relieved by mild remedies. Sometimes it appears due to a local irritation, as of the uterus.

There are some other convulsive diseases of a more local nature, dependent upon reflex action, as spasmodic asthma, which is often due to irritation of the lungs or digestive organs. Spasmodic croup often arises from the irritation of teething, or of undigested food in the stomach and bowels, producing contraction of the constrictors of the larynx. Choking results more from the spasm of the larynx, than from the pressure of the morsel upon the air passages. Tenesmus and strangury are both instances of spasm through reflex action. Abortion appears sometimes to be produced in the same manner.

SECT. 4. *Functions of the Medulla Oblongata.*

The Medulla Oblongata is the cranial prolongation of the spinal cord; it is also the medium by which the different fibres of the spinal cord are connected with the brain. Like the cord, its function is that of reflex action. Each lateral half comprises four divisions, namely, the *anterior pyramid*, the *oli-*

vary body, the *restiform body*, and the *posterior pyramid.* Their connexions are as follows:—

The Anterior Pyramids connect the antero-lateral columns of the spinal cord with the *motor* fibres of the cerebrum. A large number of their fibres decussate; those coming from the right hemisphere passing into the left side of the cord, and *vice versa*, —an arrangement which accounts for the fact that in hemiplegia, the paralysis is on the side of the body *opposite* to the lesion of the brain.

The fibres of the Anterior Pyramids, in their ascending course, chiefly enter the crura cerebri, passing through the pons varolii, and traversing the optic thalami; then they diverge, and become mingled with gray matter, thus forming the *corpora striata*, and finally radiate into the convolutions of the brain. The *non-decussating* fibres pass downwards, along with fibres of the olivary bodies, into the anterior column of the cord. The *decussating* fibres pass to the middle column of the cord.

The Corpora Olivaria are composed externally of fibrous matter. In their *upward* course, part of them proceed forwards to join the crus cerebri, and part backwards, into the corpora quadrigemina. In their course *downwards*, the fibres converge, so as to form the greater part of the anterior column of the cord. Beneath the fibrous layer is a mass of gray matter called *corpus dentatum*, continuous with the gray matter both above and below. This seems to be the centre of the respiratory nerves.

The Corpora Restiformia pass *above*, into the he-

mispheres of the cerebellum;—*below*, chiefly into the posterior columns of the cord; but a band of *arciform* fibres crosses over to the anterior columns.

The Posterior Pyramids are on each side of the posterior median furrow. Their *upward* course is, by some, supposed to be through the crura cerebri into the thalami, and so on to the convolutions;—by others, they are thought to stop short at the fourth ventricle. Below, they contribute to form the posterior column of the spinal cord.

The two important functions of a reflex nature performed by the Medulla Oblongata are *respiration* and *deglutition*. In all respects, it acts just like any segment of the spinal cord, although it *seems* to possess a distinctive character, from the mere importance of the functions that it executes.

The chief *excitor* nerve in Respiration is the Par Vagum; but the afferent portion of the Fifth pair is a strong excitor, as are also the afferent portions of all the spinal nerves conveying impressions from the general surface. The chief *motor* nerves are the phrenic and the intercostals, which, probably originate in the Medulla Oblongata: likewise the motor portions of the Par Vagum, the Facial, and the Spinal Accessory. The *ordinary* movements of respiration are performed through the Phrenic and Intercostals. The *will* also has some influence over the functions of respiration.

The function of Deglutition is of a purely reflex character. No mere effort of the will can either

produce or prevent it. When once the morsel is within the grasp of the constrictor muscles of the pharynx, we cannot avoid *swallowing*. The chief *excitor* nerve is the afferent portion of the Glosso-pharyngeal, assisted by the branches of the Fifth pair distributed upon the fauces, and the superior laryngeal, distributed upon the pharynx. The chief *motor* nerves are the pharyngeal branches of the Par Vagum, together with the Hypoglossal, the Facial, the motor portion of the Fifth, and the motor portions of some of the cervical nerves.

The acts of prehension and mastication along with sucking, are usually *voluntary* in the adult. Sometimes they are *reflex*, as in the case of the infant. The act of *suction* is also reflex in a state of coma.

In the propulsion of food down the œsophagus, so far as the muscular contraction is of a reflex character, its *excitor* nerves must be the œsophageal branches of the Par Vagum; the *motor* power being derived from the efferent portions of the same branches. The same is probably true of the movements of the stomach; though it is believed that the peristaltic movements of the whole alimentary canal are excited, independently of the nervous system, by *direct* irritation. There are other reflex actions of the Medulla Oblongata connected with the closing of the glottis, and of the pupil of the eye, which are noticed elsewhere.

The Medulla Oblongata is also believed to be the centre of the *co-ordinating* or harmonizing power for the involuntary and instinctive movements—particularly those of Respiration.

SECT. 5. *Functions of the Sensory Ganglia.*

The Sensory Ganglia are ganglionic masses lying at the base of the brain, which seem to be the centres of the nerves both of special and general sensation. In the invertebrata we find the *cephalic* ganglia, which are to be regarded chiefly as *optic* ganglia. In fishes we find the *olfactive*, *optic*, and *auditory* ganglia well developed. In man, and the higher mammals, these ganglia of special sense are much smaller in proportion to the whole encephalon; but still they can be made out. Thus the bulbous expansions of the olfactory nerves are the *olfactive ganglia*, since they contain gray or vesicular substance; and their trunks, which connect them with the brain, have their analogy in many fishes. The olfactive ganglia are more evident in those mammalia whose powers of smell are strong.

The Tubercula Quadrigemina represent the *Optic ganglia.* To these, the principal parts of the optic nerves can be traced. In man, they are much smaller than in the lower mammalia.

The *Auditory* ganglia are most distinct in certain fishes. In higher animals, they consist of small masses of gray matter lodged in the medulla oblongata.

No distinct *Gustatory ganglia* have been made out; as the sense of Taste may be considered a modification of Touch.

The Thalami Optici are, by some, regarded as the centres of common sensation, since only *sensory* nerves terminate in the tract which connects the

Olivary columns with the Thalami. The Corpora Striata have, in like manner, been considered the centres of the *motor* consensual movements.

The Tubercula Quadrigemina are the true optic ganglia, and preside over vision and also over the motor nerves of the eye. In the lower vertebrata, they appear to be the centres of the *instinctive* movements of the eye, by a reflex action. In man, they probably constitute the centres of the *consensual* or *harmonious* movements of the eye, by virtue of which the two axes are made to converge upon the same object. This action is *emotional*, and bears a strong resemblance to the instinctive movements of the lower animals.

The *muscular sense*, or that by which we are made sensible of the *tone* of the muscles, appears to be different from common sensation; it probably has its centre in the sensory ganglia at the base of the brain. A good example of the delicacy of this sense is seen in the regulation of the muscles of the voice in singing.

The emotional or instinctive acts differ from purely *reflex* acts, by the necessity existing in all cases, of sensation. The emotional acts evidently differ also from the *voluntary* acts, from the fact that often the muscles influenced by the one may be paralyzed, while they remain responsive to the power of the others. *Tickling* is an instance of an emotional act, which, like the others, always requires sensation. *Hysteria* is an example of an excited state of the emotional system: a paroxysm is often

brought on by causes producing certain sensations or emotions,—as the mere sight of another person suffering from an attack. In this way, many of the movements of mesmeric patients may be accounted for, as being of an emotional character, and excited by any powerful feeling, as a strong desire to gratify an audience, &c.

Sect. 6. *Functions of the Cephalic Nerves.*

Neither the Olfactive, Optic, nor Auditory nerves are at all endowed with common sensibility, but are solely nerves of *special* sense. They may be cut, pinched, stretched, &c., without causing any sense of pain. The common sensibility of the parts supplied by them is due to the branches of the Fifth. The common sensibility may be lost, while the special sensibility remains, and *vice versa*. No reflex movement can be excited in the Olfactive nerve, and the only reflex movement of the Optic nerve is that affecting the size of the pupil, and probably the closing of the Orbicularis muscle. In the same way, it is probable that the tension of the membrana tympani may be effected by reflex action through the auditory nerve, by means of the facial nerve.

The *decussation* of the Optic nerve is complete in those animals whose eyes have different spheres of vision; but in man, and in animals whose eyes look in the same direction, the decussation is incomplete. The true Optic nerve (which occupies the middle portion of the optic chiasm, and is dis-

tinct from its anterior and posterior commissural fibres,) is composed of two tracts,—an *external*, which passes directly outwards to the eye of that side, and an *internal*, which crosses over to the eye of the opposite side. The distribution upon the retinæ is such, that the fibres from either Optic ganglion proceed to *its own side* of *both* eyes: that is, the right optic ganglion is exclusively connected with the outer portion of the right retina and the inner portion of the left retina; whilst the left optic ganglion is, in like manner, connected exclusively with the outer portion of the left retina, and with the inner side of the right. (Mayo.) From this it follows that each Optic ganglion receives the sensations of objects on the *opposite* sides of the body. The intention of it may be to bring the visual impressions into proper harmony with the motor apparatus; so that the decussation of the motor fibres of the pyramids is *neutralized* by the decussation of the Optic nerves.

The Third, Fourth and Sixth nerves are the motor nerves of the orbit. The *Third* (Oculo-motor) is distributed to all the muscles of the eye, except the external rectus, and superior oblique. Its function is chiefly *motor;* and it is probable that the slight sensibility which it exhibits under irritation is due to anastomosis with the branches of the Fifth. Some of the muscular movements caused by the Third nerve are purely *voluntary*, as those of the levator palpebræ, and the external rectus; others again are *reflex* or *instinctive*, as those which are

directed by the inferior branch of the Third,—such as the contraction of the pupil, and the movements of the inferior oblique muscle.

The *Fourth* nerve is distributed to the superior oblique exclusively,—it is named *Patheticus,* from the idea that it caused the upward and inward motion of the eye. Its real function is the reverse. The upward and inward movement is due to the inferior oblique muscle.

The *Sixth* nerve (Abducens) is distributed solely to the rectus externus muscle, which moves the eye outwards. Both the Fourth and Sixth nerves are *voluntary.*

The *Fifth* (Trifacial) has two distinct roots, on the larger of which is a ganglion. The fibres of the smaller root do not blend with the others, till the latter have passed through this ganglion; and it can be shown by dissection, that they only pass into the inferior maxillary division of the nerve: the Opthalmic and Superior maxillary branches, being almost entirely spent upon the skin and mucous surfaces, are nerves of sensation; whilst the Inferior maxillary branch largely supplies the muscles, and is, consequently, both a motor and sensory nerve.

If the main nerve be divided within the cranium, the animal evinces signs of pain, and the sensibility of the part supplied by the nerve is destroyed. If both trunks be divided, the whole head is deprived of sensibility. If the Opthalmic branch only be divided, then the parts supplied by it lose their sensibility, but not their powers of motion; the pupil

is sometimes contracted, and sometimes dilated; and the eye-ball speedily inflames and suppurates, from a want of the natural secretion. The division of the Superior maxillary branch is also attended with a loss of sensibility, but not of motion. The different subdivisions of the Inferior maxillary have both sensory and motor powers, in different degrees. The Lingual branch seems to be chiefly sensory.

The Portio Dura of the Seventh is the *Facial nerve.* If exposed within the cranium, it exhibits only motor powers. Afterwards, it becomes partly sensory, from anastomosing with other nerves, as branches of the Fifth and of the Cervical nerves. The Portio Dura is the motor nerve of the face, and is governed both by volition and the emotions; it is also the channel of the reflex movements concerned in respiration. Its *voluntary* power may be lost, while its *emotional* or *reflex* power may be unaffected, and *vice versa.*

The general functions of the *Glosso-Pharyngeal,* are those of an *afferent* nerve, conveying impressions to the medulla oblongata, which produce reflex movements through other nerves. It is chiefly distributed to the mucous surface of the fauces and back of the tongue, and it also sends a branch forwards, to supply the edges and inferior surface of the tip of the tongue. It and the Lingual are together concerned in the sense of Taste; but the Glosso-Pharyngeal is believed to be the channel through which disagreeable impressions made on the mouth excite nausea and attempts to vomit.

The *Par Vagum* or Pneumogastric, arises from the medulla oblongata and is spent upon the pharynx, larynx, trachea, lungs, heart and stomach. Valentin has discovered that, at its roots, it possesses no motor power, but that after its inosculation with the Spinal Accessory, it exhibits motor powers. The great function of its *afferent* fibres is to convey to the medulla oblongata the impression produced by the venous blood upon the capillaries of the lungs, or of carbonic acid in the air-cells. It also conveys impressions from the larynx, trachea and bronchi, as well as from the œsophagus and stomach.

The effect of dividing the Par Vagum of *one side* is somewhat to diminish the number of inspirations, but not generally to produce disease of the lung: the functions of the nerve of that side, are also paralyzed. If both nerves be divided, the respiratory movements are very much reduced, and the animal generally dies,—but often from disordered digestion. The lungs always become congested, and as a consequence, are filled with a frothy serum. The congestion arises from the insufficient aeration of the blood, owing to the diminished respiration.

The secretion of the gastric juice was supposed to be controlled by the nerve: this is not correct; but there is a paralysis of the muscular coat of the stomach, which impairs digestion. The gastric secretion is, however, very much *influenced* by it. In the same way, the action of the heart is much

influenced, but not controlled, by the Par Vagum. The Superior Laryngeal branch is an *excitor* or afferent nerve; the Inferior Laryngeal, a *motor* nerve. The two constitute the circle of excitor and motor nerves by which the aperture of the glottis is governed.

The functions of the Spinal Accessory are chiefly motor.

The Ninth nerve or Hypoglossal, (*Motor Linguæ,*) arises from a single root, and is distributed to the muscles of the tongue, and also to those muscles of the neck concerned in the movements of the larynx. Its function is almost exclusively *motor.*

Sect. 7. *Functions of the Cerebellum.*

All vertebrated animals have a Cerebellum, though in some it is extremely small, being a mere appendage to the medulla oblongata. The most important part of it seems to be the centre, or *vermiform process.*

Its function seems in some way connected with *motion,* and chiefly with *variety* and *activity* of movement, since it is always very large in animals remarkable for active and varied movement, as the swallow, the shark, the semi-erect ape, and especially in man. Experiments go to prove that it is neither connected with sensation, volition, or reflex movements; but with the power of *associating* or *combining* various movements, as in walking, leaping, standing, or keeping the equilibrium. Patho-

logy exhibits the same facts;—thus a chronic lesion of the cerebellum seldom affects the motor functions, while it causes a want of power to harmonize the movements. So also when inflammation is confined to the membrane of the cerebellum, it does not produce delirium. Sudden *effusions* into the cerebellum, as in any other part of the encephalon, will occasion paralysis or apoplexy.

There appears sufficient reason, then, to regard the cerebellum as the great co-ordinating centre for the *voluntary* movements; just as the medulla oblongata is, for the respiratory movements. The loss of this harmonizing power is particularly well seen in *chorea.*

The Phrenological idea that the cerebellum is the seat of *sexual instinct* is without due foundation, since comparative anatomy shows a want of correspondence between the size of the cerebellum and the power of the instinct in different animals: thus it was found actually larger in geldings than in stallions or mares. Neither does pathology support the views of Gall, since the supposed connexion between disease of the cerebellum and excitement of the genital organs may be produced equally well by excitement of the spinal cord and medulla oblongata. It is *possible* that the cerebellum may be the seat of both functions, and that the excessive exercise of the one should diminish its power with regard to the other,—since it is known that great muscular exercise will diminish the sexual feelings, and *vice versa.*

Sect. 8. *Functions of the Cerebrum.*

The Cerebrum is the organ of *Intelligence*, or the voluntary adaptation of means to ends, so as to imply a perception of both. Intelligence is also estimated by the degree of *educability*. None of the invertebrata have a cerebrum, although, some of the insects, as the bee, display a remarkable degree of *instinct*. The cerebral hemispheres may be removed, and the animal not only live, but perform all the essential *organic* functions, as deglutition, suction, respiration, &c.: it also retains the power of equilibrium.

The relative amount of intelligence in different animals corresponds closely with the relative development of the cerebrum. But this development does not so much depend upon the *size* of the cerebrum, as upon the number and complexity of the *convolutions*, by which the amount of *gray* matter is augmented; and as we advance from the lower to the higher animals, there is also an increase in the *commissural fibres*.

The largest commissure of the brain is the Corpus Callosum, which unites the two hemispheres. Its fibres can be traced into the hemisphere of each side, particularly at their lower part; and they probably radiate along with the fibres from the thalami and corpora striata, to the surface of the hemispheres. The Corpus Callosum is wanting in fishes, reptiles, and birds; and it is either very incomplete, or wanting, in some of the mammals with least perfect brains. The *Anterior Commissure* unites the two

corpora striata; but many of its fibres pass through these bodies, to radiate upon the middle lobes. This commissure is particularly large where the corpus callosum is deficient. The *Posterior Commissure* unites the two optic thalami. Besides these, there are other commissural fibres, as the *Pons Tarini*, *Tuber Cinereum*, and the *Soft commissure*.

There are also *longitudinal* commissures uniting the anterior and posterior parts of the hemispheres, of which the largest is the Fornix, situated beneath the corpus callosum.

There is no direct communication between the cerebrum and cerebellum, the only commissure being the *processus a cerebello ad testes*, which passes onwards through the tubercula quadrigemina to the thalamus of either side. This alone would suggest the idea of the entire difference of their functions. We learn very little by experiments, of the functions of the different parts of the cerebrum, or of the ganglionic masses connected with it. No pain is experienced even if the whole hemispheres are removed, slice by slice; nor do convulsions ensue, either from the above experiment, or when the corpora striata or thalami are wounded. But if the tubercula quadrigemina are involved, convulsions arise. The same is true with regard to man, as far as has been observed. In cases where part of the brain has protruded and has been removed, the operation was attended with no pain, although the mental powers were perfect. Hence, the cerebrum seems to resemble the nerves of special sense, in not being

sensible to ordinary impressions. *Pressure* on the brain produces a suspension of all its powers, causing entire loss of consciousness, like profound sleep.

Experiment has revealed nothing certain as respects the function of the corpus callosum and other commissures. But it would seem that many cases of idiocy were connected with a partial or entire absence of these parts; reducing the cerebrum to the condition of that of the lower mammalia.

Pathology affords but little insight into the functions of the cerebrum. Severe lesion may exist in *one* hemisphere without any interference with the mental operations; but this is not the case when *both* hemispheres are involved. A *sudden* lesion, though comparatively trifling, will produce more severe symptoms than one much more extensive, if of a chronic nature. Thus, a sudden paralysis producing death, may result from a slight effusion in the substance of the corpora striata; but if the paralysis has followed some chronic central disorder, a much greater amount of lesion will usually be met with.

In profound sleep, the cerebral functions seem to be entirely dormant, though the spinal system, on which *reflex* action depends, is in a state of activity. The sensory ganglia also appear to be inactive in deep sleep; but where it is less profound, certain *consensual* acts are performed, which require sensation without reflection or memory,—such as turning in bed when the position becomes uneasy, or where we give some sign of recognition when our

names are called. The latter is rather an *automatic* act, and resembles those acts which are performed, when in a *revery*, in which, by frequent recurrence, certain movements are directly excited by the sensation, without the intervention of the will, which formerly was necessary. In cases of coma, or narcotic poisoning, &c., we have the same gradations as in sleep. When it is not very profound, the cerebral hemispheres seem alone to be affected; when complete, however, the sensory ganglia also are involved, and only reflex actions are performed; and if it becomes fatal, the torpor extends to the medulla oblongata, producing loss of the power of deglutition and respiration.

In *dreaming* the cerebrum appears to be partially active: sensations seem to suggest a train of thought, which, however, is not controlled by the mind. In *somnambulism*, the brain is in a still more active state, being readily affected through any of the senses, except sight. There is also a remarkable power of *balancing*, and of combining movements, which indicates great activity of the cerebellum. The faculty of *memory* resides entirely in the cerebrum. This faculty forms one of the first conditions to the reasoning process, since, without it, we must be destitute of *experience*. It is possible, if not probable, that no impression made upon the brain is ever entirely lost, except through disease; but it may be beyond the power of the *will* to recall it. It seems to depend upon the power of *association;* and a long time may elapse before the same combination of

ideas and circumstances may again occur. Sometimes it takes place in delirium, or dreaming; and ideas are recalled, of which, the mind in its healthy state, had no remembrance.

As regards the views of Phrenologists, although it is not improbable that different parts of the brain should be the seats of different faculties of the mind, still, the subject is far from being settled. Nor are their views so supported by comparative anatomy, as to remove many objections.

Sect. 9. *Functions of the Sympathetic System.*

The Sympathetic Nerve consists in a series of ganglia lying on each side of the vertebral column, communicating with the spinal nerves, and with large ganglia among the viscera. It has been named the *endo-nervous* system, to distinguish it from the cerebro-spinal, or *exo-nervous* system. The branches proceeding from the Sympathetic are not distributed to the muscles and skin, as are those of the cerebro-spinal system, but to the lungs and heart, and chiefly to the walls of the blood-vessels, which they accompany to their extreme ramifications.

Two sorts of fibres are found in the Sympathetic system,—the *white*, which are derived from the spinal nerves, and the *gray*, which belong exclusively to themselves. The trunks proceeding from the semilunar ganglia are nearly all composed of gray matter; and these are the true centres of the sympathetic system. Whatever degree of *motor* power the Sympathetic possesses,—as seen by the contrac-

tions of parts to which it is distributed on application of a stimulus,—is probably entirely due to its connexion with the cerebro-spinal system. The same is true of its sensory endowments. Commonly, the parts supplied by the Sympathetic are not at all sensible, nor are the sympathetic trunks at all so. In certain diseased conditions of these organs, pain is manifested.

The *functions* of the Sympathetic are not certainly determined; they are believed to be the channel through which the emotions and passions affect the organic functions, particularly the circulation, as seen in syncope, blushing, and turning pale. The different secretions are also very much influenced by the mental emotions. We have no precise knowledge of the distinctive function of the gray fibres: possibly they may affect the *quality* of the secretions, whilst the white fibres may regulate the *quantity*, through the blood-vessels.

CHAPTER XIV.

OF SENSATION, GENERAL AND SPECIAL.

SECT. 1.—*Of Sensation in General.*

The term Sensation signifies the *consciousness of an impression.* Properly speaking, there can be no sensation without consciousness, as in the case of reflex action, when the impression produced upon the afferent nerves is conveyed to the spinal marrow, causing motion without the consciousness of

the individual. Our sensations are commonly referred to the place where the impression is made; thus we speak of a pain in the foot or in the hand; though in reality the pain is *felt* in the brain. This is proved by two facts;—if all nervous communication between the part and the brain be cut off, no impression, however great, can be felt; and if the *trunk* of the nerve be irritated in any part of its course, the pain which is felt is referred always to the part where the nerve is distributed. To cite an example:—A blow on the ulnar nerve causes a tingling sensation at the extremities of the fingers; and the pain after an amputation, is referred, not to the stump, but to the fingers or toes that have been removed.

We are ignorant of the *mode* in which an impression—a mere physical change—is made to act upon the sensorium, so as to excite consciousness in the *mind.* The afferent nerves which connect the different parts of the body with the brain are called *sensory;* whilst those which go to the spinal marrow, and which do not produce sensations are named by Dr. M. Hall, *excitor.*

Every afferent spinal nerve, then, is made up of both sensory and excitor fibres, and those parts of the body endowed with sensory fibres are said to be *sensible.*

Sensation is divided into General and Special. *General Sensation* is that by which the body becomes sensible to surrounding objects,—causing a sense of contact, of resistance, of variation of tem-

perature, of pain, &c. *Special Sensation* is that by which we obtain impressions of a peculiar or special character, through the *special senses*, as vision, hearing, taste, &c.

General or common sensibility appears greatly to depend upon the vascularity of the part;—thus the epidermis, the hair, the nails, cartilages, ligaments, tendons, &c. have little or no sensibility, and little or no red blood circulating in them. On the contrary, the skin and other parts which are very sensitive, are also very vascular. Sometimes the non-vascular tissues become injected, as in inflammation, when they also become highly sensitive. Vascularity, however, is not invariably accompanied with a proportionate degree of sensibility, since this is not found, to any extent, in either muscles or glands, which are extremely vascular. An increased activity of the circulation of a part usually increases its sensibility; whilst a diminished activity lessens it: this is witnessed in the benumbing influence of *cold* upon the surface. The sensibility of the internal mucous membrane is less exalted by inflammation, than that of other parts; which is a wise provision, to obviate the pain that would arise from the constant movements of the viscera.

Sensations are termed *subjective* when they result from some *internal* cause;—*objective*, when produced by a material object. The subjective sensations often completely imitate the objective ones:—thus we have ringing in the ears, flashes of light, and occasionally, the senses of taste and smell, ex-

cited by *internal* causes. This, of itself, is a distinct proof that the impression produced upon the mind is due solely to the change communicated to the sensorium, and not to the change occurring at the *periphery* of the nerve.

Each of the organs of *special sensibility* requires its own peculiar stimulus to call it into action;—thus *light*, the appropriate stimulus for the eye, has no effect upon the ear;—*sound* produces no impression upon the eye;—*odours*, none upon the tongue. Hence, the inference that no nerve of *special* sensation can perform the function of any other one. Neither is it believed that the nerves of *common* sensibility can act as those of *special* sense. Electricity is said to have the power, when transmitted along the nerves of special sense, of exciting the sensations peculiar to each. Mechanical irritation of these nerves will also produce an indistinct impression: thus, irritation of the optic nerve causes a flash of light; and irritation of the auditory nerve, a sensation of buzzing in the ear. The impressions upon the nerves of special sense, when too violent, produce pain; thus, a dazzling light, intense sounds, and powerful odours excite painful sensations. The final cause of this association of pain with such violent excitement is to prevent dangerous consequences,—as is seen in cases where there is a loss of this sensibility, in consequence of which, severe lesions arise; thus violent inflammation of the air passages has been produced by the inhalation of the vapour of ammonia, in syncope.

As a general rule, violent excitement of any sensation is unpleasant, even where the moderate excitement is very agreeable. But the question of the *degree* of excitement is relative, that is, a sensation may be extremely violent to one individual, which to another more accustomed to it, would be not at all unpleasant. Thus, the sensations of heat and cold are governed by the previous condition of the parts affected; for example, by immersing one hand in hot water and the other in cold, and then placing them both in tepid water, the one will feel cool, while the other feels warm. The same thing is true of the other senses, as of vision, &c.; thus a person going from a dark room into one moderately lighted, is painfully impressed with the glare; whilst one entering from a still brighter apartment will consider it dark and gloomy.

Although the frequent recurrence of a particular sensation, is apt to produce a diminished intensity, still, the complete *stoppage* of an accustomed sensation will produce as great an impression as its first commencement; this is witnessed in persons accustomed to constant noises, as a water-fall, or a forge hammer, not being able to sleep when removed from them.

The acuteness of a particular sensation is very much influenced by *attention;* thus when the mind is entirely inactive, as in sound sleep, no sensation is produced by ordinary impressions; on the other hand, where the mind is strongly directed to them, even feeble impressions may cause acute sensations.

We may thus, by a strong effort, so direct the mind as to receive only certain impressions having reference to a peculiar train of thoughts, and be unconscious of every thing else around us, as the ticking of a clock, music, conversation, &c. This power of abstraction may be voluntary or involuntary,—the latter is termed *absence of mind*, or *revery*.

We should distinguish between the sensations and the *ideas* which result from them, and which entirely depend upon a mental process. Thus, we behold an object with our eye; a picture of it is formed upon the retina which produces a certain impression upon the optic nerve; this is conveyed to the sensorium, where a corresponding sensation is excited, resulting in the formation of an *idea* of the object.

The sensation and the idea are so closely connected, that we usually make no distinction between them. But sometimes we are liable to be deceived from this cause, as when we look upon a well-executed picture on a plane surface, of an object in relief, the *idea* of the relief is at once excited, and will not be corrected until we touch the flattened surface. We find some of these ideas, or perceptions to be *intuitive*, that is, requiring no experience. This is particularly the case with the lower animals.

It seems highly probable also, that the idea of *erect vision* is intuitive to the human infant, since there is no reason why an inverted image upon the retina should give rise to the *idea* of an inverted object, *in the mind.*

Other perceptions are *acquired*—this is the case,

for the most part, in man, whose power of acquiring perceptions, is far greater than in animals. Thus, the faculty of *measuring distances* seems intuitive in animals, but is acquired in man.

Sect. 2. *Of the Sense of Touch.*

Touch may be defined to be that modification of the general sensibility having its seat specially in the skin. In man, nearly the whole surface is endowed with it, though some parts much more than others. In animals, only certain portions of the surface are sensitive. The sense depends upon the minute distribution (or rather origin,) of nerves in the sensory papillæ. These papillæ are minute elevations on the skin, enclosing loops of the sensory nerves surrounded by a vascular plexus. The sensibility of any part may be measured by estimating the number of papillæ within a given space. It is found to be greatest at the point of the middle finger, and least over the middle of the back, and middle of the arm or thigh.

The exercise of this sense requires *contact* with the object. The only exception is with respect to temperature, the mere proximity of the hot or cold body being sufficient. It is probable that the sense of temperature is somewhat different from that of ordinary touch: it may possibly be communicated through distinct sensory fibres. It has been discovered that no mechanical irritation of the nerves of common sensation will ever excite sensations of heat

or cold; and instances are known in which the sense of temperature has been lost, while that of ordinary touch has remained, and *vice versa.*

The only idea communicated to the mind by simple Touch, is that of *resistance.* The notion of the *size* or *shape* of an object, or of the nature of its surface, can only be acquired by moving it over the sensory surface, or passing the latter over it. The *muscular sense* can only be called into action by movement. Hence, the human hand, which is capable of such a variety of movements, is so much superior, as an organ of touch, to that of any animal. The senses of Touch and Sight serve mutually to correct each other. The knowledge derived from the sense of Touch, without the aid of the other senses, is very limited, as is seen in persons born both dumb and blind. It is chiefly through the sense of Touch that we derive the idea of the *materiality* of the external world.

Modifications of this Sense.—Tickling is most readily excited in those parts which have the least tactile sensibility, as the arm-pits and soles of the feet. As regards the *temperature,* the left hand is said to be more sensitive than the right, though the converse is true with regard to common sensibility. *Extent of surface* is also concerned in this, since a weaker impression made on a large surface seems more powerful than a stronger impression made on a small surface: thus, if a single finger be put into water at 104°, and the whole of the other hand be immersed in water at 102°—the cooler water will

be thought the warmer. So, again, the finger can, without pain, be held in a liquid sufficiently warm to produce a scalding sensation when the whole hand is immersed. The sense of Touch is capable of great improvement by exercise, as is seen in the case of the blind.

Sect. 3. *Of the Sense of Taste.*

This sense appears to be a modification of that of Touch. Like it, it requires actual *contact* of the body, and it is heightened by motion of the body over the gustative surface. All bodies do not excite this sense; but as a general rule, only such as are in solution, or are soluble. Such substances are named *sapid;* others, *insipid.* The cause of this difference is not understood.

In animals, this sense is chiefly designed to direct them in search of food. The *tongue* is the principal seat of the sense of taste; but other parts of the mouth are also somewhat concerned,—as the palate. The papillæ of the tongue are essentially the same as those of the skin, though some of them rather resemble a cluster of such papillæ,—containing a fasciculus of looped capillaries, together with one of nerves. No difference of function has been ascertained to exist between the different papillæ of the tongue. When in contact with a sapid body, they often become turgid or erect, by a distention of their vessels, producing a roughness of the mucous membrane.

There is a difference of opinion as to which is the true nerve of Taste. The tongue is supplied by the lingual branch of the Fifth pair, which is distributed to the upper surface of its front, and to the papillæ near its tip; and also by the Glosso-pharyngeal, which is distributed upon the back of the tongue, and mucous lining of the fauces, and also the edges, and inferior portion of the tip,—anastomosing with the former nerve. It is probable that both the sense of Taste and Touch are conveyed by means of the lingual branch of the Fifth pair, from those parts of the tongue to which it is distributed; and that the Glosso-pharyngeal performs the same office for the parts to which it goes; and it also seems to convey to the medulla oblongata, the impressions which produce nausea and vomiting. The latter nerve is also the chief channel through which the reflex act of *swallowing* is performed. The Hypoglossal nerve is not believed to be at all connected with the sense of Taste,—its functions, as before stated, being *motor*.

It is thought by some that all our knowledge of the *flavour* of a sapid body is derived through the organs of Smell. It certainly is dependent upon that sense, as may be proved by firmly closing the nostrils, when the flavour of the substance in the mouth can scarcely be perceived. The same thing occurs when the Schneiderian membrane is inflamed, as in common cold in the head. A sapid body may excite a sensation of *irritation* or *pungency*, as well as of flavour; such sensations are evidently of the same kind as those of Touch; hence

the sense may be regarded as a compound of those of Smell and Touch.

The sense of Taste is more highly developed in animals than in man. It is capable of being rendered more acute by cultivation—as witnessed in *wine-tasters*, &c.

Sect. 4. *Of the Sense of Smell.*

The seat of this sense is the Schneiderian or pituitary membrane, upon which the olfactory nerve is distributed. The arrangemenr of the ultimate fibres of this nerve has not been ascertained: they cannot be traced to the inferior turbinated bones. A necessary condition for the sense of Smell is that the membrane should be moist. The highest part of the nasal fossæ appears to be that in which the sensibility appears to be most acute; hence we *snuff in* the air when we want to distinguish delicate odours.

Odours depend on volatile emanations from substances. These emanations, however, must be extremely minute, since they often cannot be appreciated by weight, as in the case of a grain of musk not losing any apparent weight after exposure for many years. All volatile substances, however, are not odorous—as in the case of water.

The acuteness of the sense of Smell depends greatly on the extent of the membranous surface exposed to the action of odours; hence it is far greater in some animals than in men,—thus in the deer, the dog, &c. The habit of *attention* also, as in the other senses, heightens the sense of smell, as seen in the case of the

blind, who are thus able to distinguish persons,—also in the somnambulist, and in savage tribes.

In animals, this sense is of great importance, in guiding them in the search of food, in warning them of danger, &c., but in man it is of inferior consequence.

The influence of the nasal branch of the Fifth pair is chiefly to control the secretions of the nose,—thus, if it be cut, the secretion of mucus is arrested, and the sense of Smell is nearly, if not quite, lost, in consequence of the *dryness* of the membrane. It is also the nerve of common sensibility of the interior of the nose, receiving the impressions produced by acrid and irritating substances: in fact, it is the nerve by which such matters are *felt*, whilst the Olfactory is the nerve by which *odorous* matters are *smelt*. The Fifth nerve, moreover, is the channel by which the reflex act of *sneezing* is excited; and this act will take place equally well after the Olfactory is divided, provided the Fifth remains entire.

Sect. 5.—*Of the Sense of Hearing.*

By this sense we become acquainted with the *sounds* produced by the vibrations of sonorous bodies, which vibrations are propagated through the surrounding medium, by waves or undulations. It differs from the senses just considered in this:—that the body which originates the sensation does not act directly upon the sentient nerve.

The essential part of the organ of Hearing consists in the Auditory nerve, so arranged as to receive

sonorous vibrations. In the lowest orders of animals the arrangement is very simple, being merely a nerve in contact with the solid parts of the head. Sometimes there is a cavity lined with a membrane, upon which the nerve is distributed, and filled with a watery fluid; sometimes this cavity is closed in by solid walls, through which alone the vibrations can act;—in other cases, there is an aperture covered over by a membrane.

The *Cochlea* begins to be seen in the true reptiles; it is also visible in birds; but in them it is nearly straight. In the mammalia it is spiral, forming about two turns and a half.

The ultimate distribution of the Auditory nerve (Portio Mollis of Seventh pair,) is upon the *lamina spiralis* of the cochlea, and upon the membrane lining the semi-circular canals and vestibule. There is some difference of opinion as to whether the terminations are by free papillæ, or whether the nerves form loops and return.

Certain conditions of sound to be attended to.—Sound may be transmitted through all media, whether fluid, liquid, or solid; but not through a vacuum. The transmission is more rapid through solids, than liquids; and more so through liquids than gases. The following conclusions have been established by experiment:—

I. Vibrations excited in solid bodies are transmitted to other solid bodies with greater intensity than to water; and to water with far greater intensity than to air.

II. Sonorous vibrations excited in water are imparted with considerable intensity to solids; for though they do lose something of their intensity, the vibrations appear to be returned by the solids to the liquid, so that, in reality, the sound is louder near the solid body, than it would otherwise have been.

III. Sonorous vibrations are communicated from air to water, with much greater difficulty than from air to air; but their transmission is facilitated by the intervention of a membrane between them.

IV. Sonorous vibrations in solids are weakened in passing to air; so also are the vibrations of air, in being transmitted to solids.

Now to apply these principles to the physiology of Hearing:—

In certain crustacea, and fishes, where the organ of hearing is simply an excavation in the solid part of the head, containing a liquid, and lined by a membrane on which the auditory nerve is distributed, the sonorous vibrations excited in the water are transmitted to the solid parts of the head, and thence to the contained fluid, without much loss of intensity,—according to principles I. and II. But in many fishes, the auditory cavity has an opening covered over by a membrane; in these cases the vibrations of the air would be transmitted to the liquid contained, agreeably to principle III. In most of such animals, there exist in the cavity little stony concretions termed *otolithes*, by which, the force of the vibrations of the fluid is much increased, according to principle II. Some traces of these otolithes

are found in the higher animals; but in them, their place is supplied by a more perfect arrangement.

The auditory apparatus, in its perfect form, consists of three parts, the *external*, *middle*, and *internal* ear.

The cartilage of the external ear serves to collect sounds, and to propagate them, chiefly by reflection, from the concha towards the tragus, on through the meatus; and partly to act also by *conduction*. In most animals the external ear is moveable, by which means the sounds can be collected from any quarter and concentrated towards a point.

The *meatus* serves three purposes:—the sonorous undulations are propagated through the air contained in it, directly to the membrana tympani;—the vibrations received on the external ear are conducted onwards by its walls;—and the air which it contains increases the intensity of sounds by *resonance*.

The middle ear consists of the *drum* or cavity of the tympanum, with its membrane.

The *membrana tympani* receives the sonorous undulations from the air in such a manner as to be thrown into a reciprocal vibration. This membrane, in its usual state, is rather lax; and this is the best condition for vibrating in accordance with grave sounds. By the action of the tensor tympani muscle, the membrane may be rendered more tense, and thus propagate more acute sounds. This state may be produced artificially, by forcing out air from the mouth, through the Eustachian tube, so as to cause the membrane to bulge out by the pressure within; the hearing is immediately found to be imperfect for

grave sounds,—but not for acute sounds. The tensor tympani, like the iris, is probably excited by a *reflex* action; and one of its probable uses is to protect the ear from very loud sounds, by putting the membrane in such a state of tension as not readily to reciprocate them.

The *cavity* of the tympanum, being filled with air, will propagate the vibrations of the membrane. Another of its functions is to isolate the chain of bones, so as to prevent their vibrations from being diffused through the surrounding solid parts.

The use of the *Eustachian tube* is not accurately defined. It appears to prevent a degree of dulness which would ensue if there were no such opening, —as is seen when the extremity is closed by a tumefaction of the fauces. The common idea is that it serves the same purpose as the hole of a drum, namely, to facilitate the vibrations by giving a vent. Its true office seems to be to equalize the pressure upon both sides of the membrane. It also serves to conduct off the mucus of the tympanum by means of the *cilia* of its internal surface. Hence its stoppage is one cause of deafness.

The chain of the four little bones, which connect the membrana tympani with the membrane of the *fenestra ovalis*, serves to transmit sounds to the internal ear.

The *internal ear* comprises the labyrinth or the cochlea, and semi-circular canals. These are all lined with a very delicate membrane, which is bathed in a watery fluid; and upon the membrane are spread the terminations of the Auditory nerve.

The sonorous vibrations of the air will be propagated to this fluid, the chain of bones, and the membrane of the foramen ovale, (the opening into the vestibule,) with an increased intensity, according to principle III. There is usually another opening,—the *foramen rotundum*—going into the cochlea, which is also covered by a membrane. This still farther perfects the function of hearing.

The *semi-circular canals* are three in number. They lie in different planes; and are supposed to assist in producing the *direction* of sounds.

The *cochlea* is supposed by Dugés to be connected with the *pitch* of sounds; and its development appears to be in proportion to the compass of the voice. It is peculiar in having the expansion of the auditory nerve spread out (upon the lamina spiralis,) very close to the bone, so that the vibrations of the bone may be communicated to the nerve. In cases of deafness, if no sound can be conveyed to the nerve by means of vibrations through the bony structure, we may suspect the nerve to be injured.

A single impulse to the Auditory nerve is sufficient to excite *sound;* but it requires a succession of such impulses to constitute *tone.* The *pitch* of tones depends upon the number of vibrations in a given time; the high notes being produced by the most rapid vibrations, and the low notes by the slowest. The most acute sound that the ear can appreciate, is that produced by twenty-four thousand impulses per second; and the gravest tone capable of being heard, is one produced by seven or eight impulses in a second.

There is a difference in this respect, however, in the ears of different persons. The *loudness* of musical tones depends upon the force and extent of the vibrations communicated by the sounding body to the medium. We are ignorant of the cause of the difference in the *timbre* or quality of musical tones: it may depend on a difference of form in the undulations.

Our ideas of the *direction* of sounds are acquired by habit; we may be assisted, also, by the relative intensity of the impressions upon the two ears. As regards the idea of *distance*, we are guided chiefly by the loudness or faintness of the sound; hence the ear may be deceived, as well as the eye, in making this estimate,—as seen by the imitation of a distant band of music approaching, by a *crescendo* of concealed instruments; and so also, in the ventriloquist.

An important office of the sense of Hearing is to supply the sensations by which the voice is regulated. Hence, persons who are born deaf, are necessarily dumb also, even though there be no defect in their organs of voice.

Sect. 6.—*Of the Sense of Sight.*

By this sense we become acquainted with Light and with luminous bodies. Two theories of light are maintained: one, that it depends on rays emitted from luminous bodies; the other, that it depends on undulations of an ether. The *laws* of light are the same, whichever of these theories be adopted.

Light travels in straight lines, through a uniform medium. When a ray of light passes from a rarer to a denser medium, it is bent or *refracted* towards

a perpendicular;—when passing from a denser to a rarer medium, it is refracted *from* a perpendicular.

In consequence of this law of refraction, if parallel rays fall upon a double convex lens, they will be converged to a focus, upon the other side. An object placed at a distance from such a lens, will form an inverted image upon the opposite side, on a skreen placed at the focal distance. The farther the object is removed from the lens, the nearer will the picture be brought to it, and the smaller will it be. If the skreen be not precisely in the focus of the lens, the picture will be indistinct; if too near the lens, the rays will not have met,—if too far, the rays will have crossed each other.

The Eye is an optical instrument of great perfection. The rays of light proceeding from an object and falling upon the cornea, are made slightly to converge; then passing on to the crystalline lens, they converge still more, so as to cause an inverted picture of the object to be formed upon the retina, or expanded surface of the Optic nerve, by which the impression is conveyed to the brain.

The *pigmentum nigrum* is spread beneath the retina, and lines the choroid coat. Its object is to absorb the rays of light after they have passed through the retina, and thereby prevent their being reflected from the interior of the globe,—which would cause indistinctness in the picture. This difficulty occurs in *albinos*, in whom there is a deficiency of the pigment, and where there is, consequently, imperfect vision.

There are two defects in common convex lenses:

the one, termed *spherical aberration*, results from the fact that *all* the rays passing through the lens do not converge at the same focal length; this causes rather an obscure image, unless the central portion of the lens only be employed. The other defect is called *chromatic aberration*, and results from the different refrangibility of the different colours of white light: this will cause a *coloured* image. In practice, these difficulties may be corrected by combining lenses of different densities and curvatures. This is admirably provided for in the eye, by the combinations of *humours* of different densities and curvatures.

The Eye, however, is liable to two opposite conditions of deficient vision:—*myopia*, or short-sightedness, and *presbyopia*, or far-sightedness. In the former, the cornea may be too convex, and the refractive power of the humours too high,—causing the image to be formed in front of the retina, instead of directly upon it. In such cases, a distinct image can only be formed by bringing the object close to the eye. It is corrected by the use of *concave* glasses. The other (*presbyopia*) depends upon a too flat cornea, and a too low refractive power of the humours. In consequence of this, the rays converge at a focus *behind* the retina;—here, the remedy is the use of *convex* glasses, or withdrawing the object to a greater distance, which brings the focus of the eye nearer to its front. This state is well marked after the operation for cataract, when the removal of the lens greatly diminishes the refractive power of the eye.

The power of accommodating the eye to distances has never been fully explained. It is probable that a change occurs both in the convexity of the lens and cornea, and in the relative position of the retina and lens. The form of the globe of the eye may be altered by the action of the muscles, so as to elongate it, and thus increase the curvature of the cornea; and a change may also take place in the figure and position of the crystalline lens, and also in the aperture of the pupil.

The Optic nerve, at its entrance into the eye, divides into a number of small fasciculi, which are spread out and form a net-like plexus, which is the outer layer of the retina. The surface of the retina next to the vitreous humour, is composed of minute papillæ, closely packed together. Each papilla contains an ultimate nerve fibre. A layer of cells is interposed between the papillæ. The size of the papilla has been supposed to determine the size of the smallest object which could be seen by the unaided eye. The retina is well supplied with capillary vessels.

The reason why we see objects *erect* when they are represented upon the retina *reversed*, can be explained only by referring it to the *mental* act which takes cognizance of the impression. It is not at all necessary that an inverted image upon the retina should give the *idea* of inversion to the mind.

The cause of *single* vision, when both eyes are used, seems to depend very much on habit. The only condition that is necessary is that the images should fall upon the parts of the two retinæ which

are accustomed to act together: thus, if while looking steadily at an object, we press one eye-ball, so as to change the position of the image, we see two representations of the object. The same thing takes place in strabismus, and in various disorders of the nervous system; but if this morbid condition becomes permanent, the individual does not continue to see double, but becomes accustomed to the new position of the images.

The perception of the impressions made upon the retina is purely a *mental* process; and this may be either intuitive or acquired;—the latter is most common in man; the former, in animals. The idea of *solid* forms is entirely acquired through the aid of *touch*,—as is proved in the case of a person affected with congenital cataract, who had afterwards been restored to sight, regarding every object as a flat surface.

The idea of the *distance* of objects arises also from the association of the tactile with the visual sensations. In regard to near objects, the degree of the *convergence* of the eyes may assist; in regard to very distant objects, we judge by the apparent size, of their distance, if their real size is known to us; but if we are ignorant of this, then we judge by the greater or less distinctness of the object; and hence, we are liable to be deceived. The estimate of the size of an object is closely connected with that of its distance, and is dependent, chiefly, upon the degree of convergence of the axes of the two eyes: this is particularly the case for objects very near to us; in more distant objects we may be

easily deceived. The association between our tactile and visual impressions enables us to judge of *smoothness*, (a quality essentially the object of touch,) by vision merely; also of *polish*, which, though essentially the object of sight, is easily recognised by the touch.

The *contraction* of the pupil under the stimulus of light, is effected by the muscular contraction of the iris. It is purely a *reflex* act,—the impression being conveyed to the nervous centres by the optic nerve, and the motor power transmitted to the iris, by the Third pair. It is entirely independent both of the will and consciousness of the individual. The *dilatation* of the pupil is probably due to the elasticity of the iris. The design of the contraction of the pupil is to exclude any injurious amount of light from the interior of the eye. There is a certain contraction of the pupil which takes place without any change in the amount of light;—it occurs when the two eyes are made strongly to converge upon a near object; and the purpose seems to be to prevent the rays from entering at such a wide angle as would form an indistinct image.

There is a tendency in the luminous impressions made upon the eye, like those made upon the ear, to remain for a short interval. This duration of the visual impression is familiarly seen by causing a luminous body to whirl around : it is found to vary from one fourth to one tenth of a second.

The impressions of *colour* are produced by the differently coloured rays which objects reflect or transmit to the eye. Some persons are not able to

distinguish colours, though in other respects their vision is perfect.

CHAPTER XIV.

OF THE VOICE.—SPEECH.

Vocal sounds and articulate language, or *speech*, are entirely distinct, and are produced at different places,—the *larynx* being the instrument of the voice, and the *mouth*, that of language.

The *voice* is produced by a modification of muscular action. In all air-breathing vertebrata the production of sound depends upon the passage of air through a certain portion of the respiratory tube, so constructed as to be made to vibrate.

In reptiles, the vibrating apparatus is very simple, being composed of a slit bounded by two contractile lips: the only vocal sound of these animals is a *hiss*. In birds, the vocal apparatus is at the lower extremity of the trachea, at its subdivision; it is very complicated in singing birds, but the arrangement for their breathing is much the same as in reptiles. In mammals, the vocal organ and the regulator of respiration are associated in the larynx. Man alone has the faculty of *language*.

The cricoid cartilage forms the summit of the trachea. It is a bony ring, deeper behind than before; and it articulates with the thyroid cartilage by means of the lower cornua of the latter, in such a way as to form a little depression between the two in front. The two arytenoid cartilages are placed upon the upper surface of the back of the cricoid, and are so

articulated as to enable them to be approximated, or separated from each other. The *vocal chords* or vocal ligaments (thyreo-arytenoid) extend from the tops of the arytenoid cartilages across to the front of the thyroid cartilage. They are composed of yellow fibrous, or elastic tissue. It is upon the condition of these ligaments that the different modifications of the voice depend. They are made tense by the depression of the front of the thyroid cartilage as it approaches the cricoid, and relaxed by its elevation; by this action the *pitch* of sound is regulated. Again, they are brought into more or less close apposition by the rotation of the arytenoid cartilages;—this arrangement is necessary for the perfection of *tone*. The *rima glottidis* is the clink or fissure between the vocal chords: when there is no sound, it assumes the shape of the letter V.

Hence, there are two sets of movements concerned in vocalization:—the regulation of the relative position of the vocal chords, and the regulation of their tension. The first is accomplished by means of the arytenoid cartilages, which are made to diverge by the action of the crico-arytenoidei-postici muscles; by this means the vocal ligments are drawn asunder, and the rima-glottidis opened. The second, or that concerned in the tension of the ligaments, is effected by the approximation or separation of the thyroid and cricoid cartilages in front; thus, they will be made tense by the contraction of the crico-thyroidei muscles, assisted by the sterno-thyroidei; and they will be *relaxed* by the action of the thyro-arytenoi-

dei muscles, aided by the thyro-hyoidei. The muscles which govern the aperture of the glottis are also intimately connected with respiration. By an effort of will, we can close the glottis, through their means; and a spasmodic movement of this sort occurs in coughing and sneezing, whereby irritative substances are expelled. The *nerve of motion* for these muscles is the inferior or recurrent Laryngeal;—the *afferent* or *sensory* nerve is the superior Laryngeal; if it be divided, no reflex respiratory movement can be excited by irritating the lining membrane of the larynx.

When in a state of rest, as during ordinary respiration, the vocal chords appear to be as much relaxed as possible, and widely separated from each other. In order to produce a vocal sound, they must be approximated, and at the same time put to a certain degree of tension. Both these movements take place at the same time. The size of the aperture between the vocal ligaments varies with the *note*, being smaller in proportion as the note is high.

It has been satisfactorily proved that the vocal ligaments do not act either as vibrating strings, nor to the flute-pipe of any organ; but as *reed-instruments*, such as the clarionet, hautboy, &c. The production of *falsetto* notes is not clearly accounted for.

The will has the wonderful power of determining the exact tension of the vocal chords, for the production of every variation of sound. It has been estimated by Müller that the difference in the length of the vocal ligaments between the states of tension and repose, in the male, is one-fifth of an inch;—in

the female, not more than one-eighth of an inch. As the natural compass of the voice is about two octaves, or twenty-four semi-tones, and as a singer can produce at least ten distinct intervals within each semi-tone, there would be two hundred and forty distinct states of tension for the vocal cords, every one of which can be estimated by the will; and as the extreme variation in their length is only one-fifth of an inch, the variation required to pass from one state of tension to another, will only be the 1-1200th of an inch. This estimate is even lower than necessary for a practised vocalist. Madame Mara could sound fifty intervals between each semi-tone:—the compass of her voice was at least forty semitones; hence, the variations were only the ten-thousandth of an inch.

The *pitch* of the voice is lower in males than in females, on account of the greater length in the vocal ligaments; but this difference does not arise till the period of puberty. The *timbre* or quality of the voice probably depends, in part at least, upon the degree of flexibility and smoothness of the cartilages of the larynx; thus, in women and children the voice is clear and smooth, and in them the cartilages are soft and yielding. The *loudness* of the voice depends a good deal upon the force with which the air is expelled from the lungs; but partly, also, upon the vibrations, of the other parts of the larynx and neighbouring cavities increasing the resonance. *Song* depends upon the regulation of the vocal cords, by the power of will, by which definite and sustained musical tones are produced. In man, the power of

song is entirely acquired. In ordinary conversation, the voice is *modulated,* that is, passes through a variety of musical tones.

Articulate sounds, or *speech,* are not produced in the larynx, but in the buccal cavity. A *whisper* is an articulate sound without any laryngeal tone; and all that is requisite to produce it is the propulsion of air through the mouth from behind forwards. Ordinary speech is a modification of the laryngeal tone by the mouth. The simplest form of speech is the sounding of the *vowels,* which are chiefly formed by modifications in the form of the buccal passages, and are capable (with the exception of *i,*) of being prolonged for any length of time.

In pronouncing the *consonants,* there is more or less stoppage of the breath. These are divided into *continuous* and *explosive,* according as the breath, is more or less completely stopped just before the pronunciation.

Stammering depends upon a want of control by the will, over the muscles of articulation, which are often spasmodically affected. There is considerable analogy between it and a local *chorea:* they are both increased by the excited emotions. The greatest difficulty of the stammerer consists in pronouncing the explosive consonants;—the interruption of the breath which they occasion, being involuntarily continued beyond the proper time.

INDEX.

This Index is not intended to be a perfect one. Its design is merely to supply the want of reference to many subjects not embraced in the Table of Contents. The numbers refer to the pages.